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LRPDS INTERIM TECHNICAL REPORT. APPENDICES,(U)
JUN 71 S ATTWOOD DAAK02-71-C-0022

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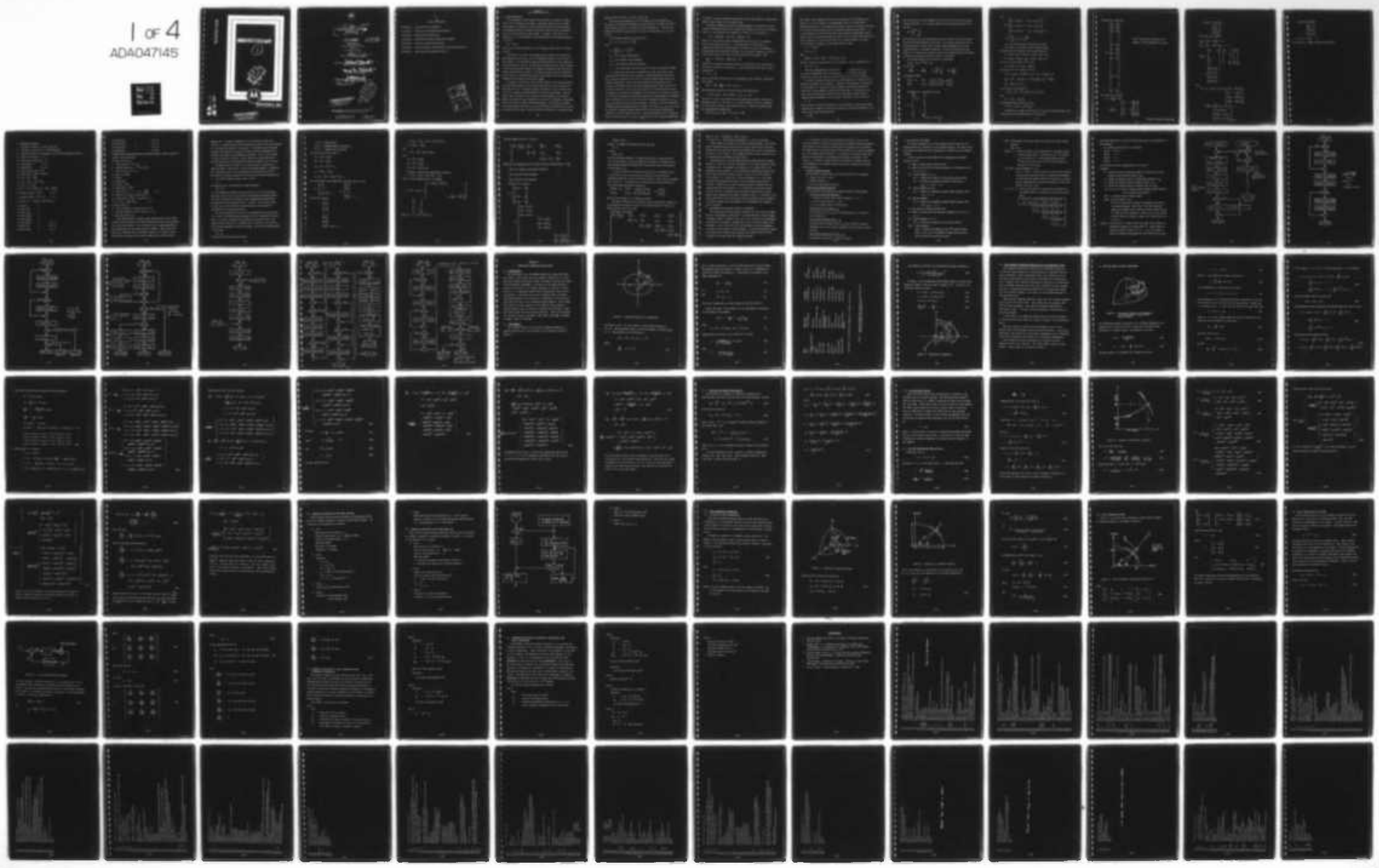

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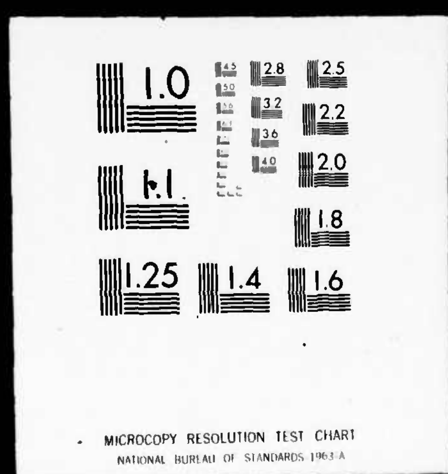

4.21 form $\Sigma C_i^T U_i T_i$ $(3J \times J)$

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MOTOROLA INC.
Government Electronics Division

14 DEC 1972

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LRPDS
INTERIM TECHNICAL REPORT, [redacted]
APPENDICES,

(11) 15 Jun[redacted]71 (12) 325p.

PRESENTED TO

Surveying and Geodesy Division

USAETL

Fort Belvoir, Virginia

(15)

Contract No. DAAK02-71-C-~~0~~022

Approved by: [signature]

J. Barto, Section Manager

[signature]

H. Stuart, Project Manager

Prepared by: [signature]

(10) S. Attwood, Systems Manager

522775

MOTOROLA *Government Electronics Division*

8201 E McDOWELL ROAD, SCOTTSDALE, ARIZ 85252

401679

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APPENDIX A
DATA REDUCTION PRINCIPLES

1. PROBLEM FORMULATION

The simultaneous reduction method with constraints is achieved by finding values for all variables which minimize a functional comprised of the weighted sum of squares and differences between measured data and the observation model, and differences between the solution vector and a vector of apriori information about all of the parameters being estimated. In general if the vector Q is comprised of all of the parameters being estimated and the observational equation is given by:

$$M_{jk} = G_{jk}(Q)$$

where M_{jk} is the measured quantity at the j^{th} ground station of the k^{th} aircraft location.

The function $G(Q)$ relates the parameters being estimated to the quantities being measured and, therefore, forms the observation equations for the system of data reduction. For the LRPDS the quantities being measured are range changes at each ground station location. The data from each ground station is then a sequence of time differences which represent the changes in propagation time for each read command received from the aircraft. By suitable scaling, these time differences may be considered as representing changes in range between the first received read command and any succeeding received read commands.

For purposes of discussion, then, the data available to be reduced represents the range change between the first aircraft location seen and all successive aircraft locations seen. The ground receivers each contain a local oscillator which is used as a standard to measure elapsed time and hence range change. Since the ground station oscillator is not at exactly the same frequency as the aircraft reference oscillator and may be drifting at a fixed rate in frequency, the measured data will contain the effects of these discrepencies. The observation equation then contains terms which reflect not only the frequency offset and drift, but also an arbitrary initial range (or phase) term which corresponds to the range from the

ground station to the first aircraft location seen.

The initial range parameter for the j^{th} ground station is designated a_{0j}. The effect of the frequency differences between the aircraft oscillator and the j^{th} ground station oscillator is contained in a term designated a_{1j}. The drift rate between the aircraft and ground station oscillator is designated a_{2j} for the j^{th} station.

The observation equation G_{jk} is then given by

$$G_{jk} = r_{jk} - a_{0j} + a_{1j}t_k + a_{2j}\frac{t_k^2}{2}$$

where

$$r_{jk} = \left(\sum_{m=1}^{3} (q_{mk} - p_{mj})^2 \right)^{1/2}$$

a_{0j} is the initial range parameter

a_{1j} is the frequency offset parameter

a_{2j} is the frequency drift rate parameter

t_k is the time between the first and the k^{th} aircraft interrogation command.

It is worth note at this point to indicate that in fact the effects of the oscillator offset and drift will be dependent on the time difference between the first aircraft interrogation time seen by a particular ground station and the succeeding interrogations. Thus, a particular ground station might first see the aircraft on the second, third or any later interrogation time rather than the first. It would be possible to include this exact situation in the data reduction only at the expense of a considerable rearrangement of the structure of the matrices involved. In so far as the positions of the ground stations such a reorganization is unnecessary since an arbitrary shift in the zero time point only changes the values of a_{0j}, a_{1j}, and a_{2j} recovered by the data reduction procedure. Therefore, to preserve the matrix structure (without detrimental effect on accuracy) the values of a_{0j}, a_{1j} and a_{2j} will be estimated as though all ground stations saw the first aircraft interrogation (whether or not any of them actually did). The only implication of this procedure is that if the actual values of a_{1j} and a_{2j} are desired (for test purposes perhaps) then

the results of the data reduction procedure will require some additional interpretation beyond a direct readout of the estimated values.

The apriori information about the estimated parameters is contained in a vector Q_e and a covariance matrix W_2^{-1} which contains the estimates of the error in the apriori vector Q_e. The functional to be minimized by a choice of $\hat{Q}$ is then given by

$$F = \left[M - G(Q)\right]^T W_1 \left[M - G(Q)\right] + \left[Q_e - Q\right]^T W_2 \left[Q_e - Q\right] ,$$

where W_1 is the covariance matrix of measurement error and W_2^{-1} is the covariance matrix of the apriori errors in Q_e. The minimization of the functional F is accomplished by partially differentiating F with respect to each of the parameters being estimated then equating the resultant set of (nonlinear) equations to the zero vector and solving for the value of Q which satisfies these equations. Then

$$\frac{\partial F}{\partial \hat{Q}} = 0 = -A^T(Q)W_1 \left[M - G(Q)\right] - W_2 \left[Q_e - Q\right]$$

where $A(Q)$ is the matrix of partial derivatives of the function $G(Q)$ with respect to the vector Q evaluated at the value of Q. At the solution point the vector Q may be represented as

$$Q = Q_T + \delta Q$$

where Q_T represents the true values of the parameters being estimated. The function $G(Q)$ is then

$$G(Q) = G(Q_T) + \frac{\partial G}{\partial Q_T} \delta Q = G(Q_T) + A(Q_T)\, \delta Q .$$

Substituting this value for $G(Q)$ into the above relationship gives

$$0 = -A^T(Q_T)\, W_1 \left[M - G(Q_T) - A(Q)\delta Q\right] - W_2\, (Q_e - Q_T - \delta Q) .$$

The vector $M - G(Q_T)$ is, by definition of the observational equation, the vector of measurement errors δR. The vector $Q_e - Q_T$ will be defined to be $\mathring{\delta} Q$ for convenience (it is the vector of errors in the apriori vector Q_e). Making these substitutions and rearranging the equation gives:

$$\left[A^T(Q_T)\, W_1\, A(Q_T) + W_2\right]\delta Q = A^T\, (Q_T)\, W_1 \delta R + W_2 \mathring{\delta} Q.$$

The solution of this equation for δQ would give the errors in the estimated parameters (i.e., δQ) as a function of the measurement error, δR, and the apriori information errors, $\dot{\delta Q}$. This equation also provides a basis for solving for the value of the vector Q which satisfies the set of nonlinear equations derived above. If δR is interpreted as the current difference vector between the measurements and the current value of the observation equation, and $\dot{\delta Q}$ is the difference vector between the apriori estimate of Q and the current value of Q a recursive method of finding Q can be formulated. Suppose $\hat{Q}_i$ is the present value of Q then

$$\delta R_i \equiv M - G(\hat{Q}_i) ,$$

$$\delta Q_i \equiv Q_e - \hat{Q}_i .$$

Then

$$\left[A^T(\hat{Q}_i)\, W_1\, A(\hat{Q}_i) + W_2\right]\delta Q_i = A^T(\hat{Q}_i)\, W_1 \delta R_i + W_2 \dot{\delta Q}_i ,$$

defines a value for δQ_i which may be used to determine a better estimate of $\hat{Q}_i$ or

$$\hat{Q}_{i+1} = \hat{Q}_i + \delta Q_i$$

The overall procedure then to start with an initial estimate of $\hat{Q}_0 = Q_e$ (the apriori information), the two covariance matrices W_1^{-1} and W_2^{-1}, and then iterate the value of the vector $\hat{Q}_i$ until the correction δQ_i is the zero vector.

The matrix of partial derivatives of $G(Q)$ with respect to Q is defined in the previous development to be the matrix A. Because of the dimensions of the matrix A, the requirements for storage of the various matrices involved would exceed the capabilities of most computers considered for field usage. The structure of the matrix allows partitioning so that the sizes of the matrices involved and the computer storage requirements are both reduced. The matrix A can be written as

$$A = \frac{C}{B}$$

where the matrix C contains the partials of $G(Q)$ with respect to the ground station parameters and B contains the partials with respect to the aircraft locations. The vector δQ may then be partitioned into

$$\delta Q = \frac{\delta p}{\delta q}$$

with δp the vector of station parameter corrections and δq the vector of aircraft location corrections. It is further assumed that the covariance matrix W_2^{-1} is of the form

$$W_2^{-1} = \begin{bmatrix} W_p^{-1} & 0 \\ 0 & W_q^{-1} \end{bmatrix}$$

where W_p^{-1} and W_q^{-1} are the covariance matrices of the apriori errors in the ground station and aircraft parameters respectively. This implies that there is no correlation between the apriori errors in ground station parameters and aircraft parameters which is a reasonable assumption. With these definitions the basic equation to be solved can be restated in terms of the separate matrices and vectors relating to the ground and aircraft portions of the problem.

The original equation to be solved for δQ is given by:

$$(A^T W_1 A + W_2)\delta Q = A^T W_1 \delta R + W_2 \delta\dot{Q}$$

so that with

$$A = \left[\frac{C}{B}\right] ; \qquad Q = \begin{bmatrix} \delta p \\ \delta q \end{bmatrix} ; \qquad W_2 = \begin{bmatrix} W_p & 0 \\ 0 & W_q \end{bmatrix} ; \qquad \delta\dot{Q} = \left[\frac{\delta\dot{p}}{\delta\dot{q}}\right]$$

the equation becomes

$$\begin{bmatrix} C^T W_1 C + W_p & C^T W_1 B \\ B^T W_1 C & B^T W_1 B + W_q \end{bmatrix} \begin{bmatrix} \delta p \\ \delta q \end{bmatrix} = \begin{bmatrix} C^T W \\ B^T W_1 \end{bmatrix} \delta R + \begin{bmatrix} W_p \delta\dot{p} \\ W_q \delta\dot{q} \end{bmatrix}$$

The matrix B^T is structured as follows

$$B^T \equiv \begin{bmatrix} -B_2^T & & & & & \\ & -B_3^T & & & & \\ & & \cdot & & 0 & \\ & & & \cdot & & \\ & & & & \cdot & \\ & & & & & \cdot \\ 0 & & & & & -B_K^T \end{bmatrix}_{3(K-1) \times J(K-1)} \quad J>3$$

and

$$B_i^T \equiv \begin{bmatrix} (q_{1i} - p_{11})/r_{1i} & \cdots & (q_{1i} - p_{1J})/r_{Ji} \\ (q_{2i} - p_{21})/r_{1i} & \cdots & (q_{2i} - p_{2J})/r_{Ji} \\ (q_{3i} - p_{31})/r_{1i} & \cdots & (q_{3i} - p_{3J})/r_{Ji} \end{bmatrix}_{3 \times J}$$

$$r_{jk} = \left(\sum_{n=1}^{3} (q_{nk} - p_{nj})^2 \right)^{1/2}$$

q_{nk} is the n^{th} coordinate of the k^{th} A/C location

p_{nj} is the n^{th} coordinate of the j^{th} ground station.

Expanding the matrix equations into two equations gives,

1) $(C^T W_1 C + W_p)\delta p + C^T W_1 B \delta q = C^T W_1 \delta R + W_p \dot{\delta} p \equiv \delta Z_1$

2) $B^T W_1 C \delta p + (B^T W_1 B + W_q)\delta q = B^T W_1 \delta R + W_q \dot{\delta} q \equiv \delta Z_2$.

Solving the second equation for δq gives

$$\delta q = (B^T W_1 B + W_q)^{-1} (\delta Z_2 - B^T W_1 C \delta p).$$

Substituting for δq in equation 1) gives

$$(C^T W_1 C + W_p)\delta p + C^T W_1 B (B^T W_1 B + W_q)^{-1} (\delta Z_2 - B^T W_1 C \delta R) = \delta Z_1$$

$$\left[W_p + C^T W_1 C - C^T W_1 B (B^T W B + W_q)^{-1} B^T W_1 C\right]\delta p = \delta Z_1 - C^T W_1 B \hat{\delta} Z_2$$

$$\hat{\delta} Z_2 = (B^T W_1 B + W_q)^{-1} \delta Z_2 \ .$$

Let the matrix V be defined by

$$V = \left[W_p + C^T W_1 C - C^T W_1 B \ (B^T W_1 V + W_q)^{-1} \ B^T W_1 C\right] .$$

Then

$$\delta p = V^{-1}(\delta Z_1 - C^T W_1 B \hat{\delta} Z_2).$$

Substituting back to solve for δq gives

$$\delta q = \hat{\delta} Z_2 - (B^T W_1 B + W_q)^{-1} B^T W_1 C \delta p \ .$$

The matrix W_1 is diagonal with entries $1/\sigma^2$ so that the constant value σ^2 can be moved into the constraint matrices W_p and W_q thus:

The vector $\dot{\delta p}$ is made up of

$$\dot{\delta p} \equiv \begin{bmatrix} p_{11} - \hat{\hat{p}}_{11} \\ p_{21} - \hat{p}_{21} \\ p_{31} - \hat{p}_{31} \\ \cdot \\ \cdot \\ \cdot \\ p_{1J} - \hat{p}_{1J} \\ p_{2J} - \hat{p}_{2J} \\ p_{3J} - \hat{p}_{3J} \\ a_{0j} - \hat{a}_{0j} \\ \cdot \\ \cdot \\ \cdot \\ a_{1j} - \hat{a}_{1j} \\ \cdot \\ \cdot \\ \cdot \\ a_{2j} - \hat{a}_{2j} \end{bmatrix} .$$

where $\hat{\hat{x}}$ is the apriori estimate of the parameter x being estimated from the data.

The vector δZ_1 is given by

$$\delta Z_1 = \sigma^2 W_p \dot{\delta p} + C^T \delta R ,$$

$$= \sigma^2 W_p \dot{\delta p} + \begin{bmatrix} -C_2^T & . . . & -C_K^T \\ I & & I \\ -T_2^T & . . . & T_K^T \\ -\dot{T}_2^T & . . . & -T_K^T \end{bmatrix} \begin{bmatrix} \delta r_2 \\ \cdot \\ \cdot \\ \cdot \\ \delta r_K \end{bmatrix} ,$$

(equation continued on next page)

$$= \sigma^2 W_p \dot{\delta} p + \begin{array}{c} \begin{bmatrix} -\Sigma C_i^T \delta r_i \\ \Sigma \delta r_i \\ -\Sigma T_i^T \delta r_i \\ -\Sigma \dot{T}_i^T \delta r_i \end{bmatrix} \end{array} \begin{array}{c} 3J \\ J \\ J \\ J \end{array} .$$

The vector δZ_2 is given by

$$\delta Z_{2i} = -B_i^T \delta r_i + \sigma^2 W_q^i \dot{\delta} q^i \quad 3 \times 1 .$$

$$\hat{\delta} Z_{2i} = (B_i^T B_i + \sigma^2 W_q^i)^{-1} \delta Z_{2i} \quad 3 \times 1 .$$

$$C^T B \hat{\delta} Z_2 = \begin{bmatrix} -C_2^T & \cdots & -C_K^T \\ I & & \\ -T_2^T & \cdots & \\ -\dot{T}_2^T & & \end{bmatrix} \begin{bmatrix} -B_2 & & 0 \\ & \ddots & \\ 0 & & -B_K \end{bmatrix} \begin{bmatrix} \hat{\delta} Z_{22} \\ \vdots \\ \hat{\delta} Z_{2K} \end{bmatrix} ,$$

$$= \begin{bmatrix} \Sigma C_i^T B_i \hat{\delta} Z_{2i} \\ -\Sigma B_i \hat{\delta} Z_{2i} \\ \Sigma T_i^T B_i \hat{\delta} Z_{2i} \\ \Sigma \dot{T}_i^T B_i \hat{\delta} Z_{2i} \end{bmatrix} \begin{array}{c} 3J \\ J \\ J \\ J \end{array} :$$

Then,

$$\hat{\delta} Z_1 = \delta Z_1 - C^T B \hat{\delta} Z_2 = \sigma^2 W_p \dot{\delta} p + \begin{bmatrix} -\Sigma C_i^T \delta r_i - \Sigma C_i^T B_i \hat{\delta} Z_{2i} \\ \Sigma \delta r_i + \Sigma B_i \hat{\delta} Z_{2i} \\ -\Sigma T_i^T \delta r_i - \Sigma T_i^T B_i \hat{\delta} Z_{2i} \\ -\Sigma \dot{T}_i^T \delta r_i - \Sigma \dot{T}_i^T B_i \hat{\delta} Z_{2i} \end{bmatrix} ,$$

$$= \sigma^2 W_p \dot{\delta} p + \begin{bmatrix} -\Sigma C_i^T (\delta r_i + B_i \delta Z_{2i}) \\ \Sigma(\delta r_i + \Sigma B_i \hat{\delta} Z_{2i}) \\ -\Sigma T_i^T (\delta r_i + B_i \hat{\delta} Z_{2i}) \\ - \Sigma \dot{T}_i^T (\delta r_i + B_i \hat{\delta} Z_{2i}) \end{bmatrix}$$

$$= \sigma^2 W_p \dot{\delta p} + \begin{bmatrix} -\Sigma C_i^T \delta Z_3 \\ \Sigma \delta Z_3 \\ -\Sigma T_i^T \delta Z_3 \\ -\Sigma \dot{T}_i^T \delta Z_3 \end{bmatrix} \begin{matrix} 3J \\ J \\ J \\ J \end{matrix}$$

$$\delta Z_3 \equiv \delta r_i + B_i \hat{\delta} Z_{2i} \quad J \times 1$$

The vector $\delta Z_1 - C^T B \hat{\delta} Z_2$ is required along with $\hat{\delta} Z_2$.

2. COMPUTATION PROCEDURE

1. Initialize a vector $6J \times 1$ with $\sigma^2 W_p \dot{\delta}_p$ $(\hat{\delta}Z_1)$
2. Initialize a vector $3(k\text{-}1) \times 1$ with $\sigma^2 W_q \dot{\delta}_q (\hat{\delta}Z_{2i})$
3. Initialize a matrix to be diagonal $\sigma^2 W_p$ to store the coefficient matrix V
4. Start a "do" loop on $i = 2, k$

4.1 form matrix B_i and save $(J \times N)$

4.2 form matrix B_i^T $(N \times J)$

4.3 product $B_i^T B_i$ $(N \times N)$

4.4 add $\sigma^2 W_q^i$ to get $B_i^T B_i + \sigma^2 W_q^i$

4.5 invert $(B_i^T B_i + \sigma^2 W_q^i)^{-1}$ and save

4.6 $\hat{\delta}Z_{2i} = \hat{\delta}Z_{2i} - B_i^T \delta r_i$

4.7 $\hat{\delta}Z_{2i} = (B_i^T B_i + \sigma^2 W_q^i)^{-1}\, \hat{\delta}Z_{2i}$

4.8 $\delta Z_3 = \delta r_i + B_i \hat{\delta}Z_{2i}$

4.9 $\hat{\delta}Z_1 = \hat{\delta}Z_1 + [-C_i^T \delta Z_3,\ \delta Z_3,\ -T_i^T \delta Z_3,\ -\dot{T}_i^T \delta Z_3]^T$

4.10 product $B_i(B_i^T B_i + \sigma^2 W_q^i)^{-1}$ $(J \times N)$

4.11 product $B_i(B_i^T B_i + \sigma^2 W_q^i)^{-1}\, B_i^T$ $(J \times J)$

4.12 form $U_i = I - B_i(B_i^T B_i + \sigma^2 W_q^i)^{-1}\, B_i^T (J \times J)$

4.13 form ΣU_i *

4.14 form $-\Sigma T_i^T U_i$ *

4.15 form $-\Sigma \dot{T}_i U_i$ *

4.16 form $+\Sigma T_i^T U_i T_i$ *

4.17 form $\Sigma \dot{T}_i^T U_i \dot{T}_i$ *

4.18 form $\Sigma T_i^T U_i \dot{T}_i$ * $(J \times J)$

4.19 form $C_i^T U_i$ * $(3J \times J)$

4.20 form $-\Sigma C_i^T U_i$ * $(3J \times J)$

4.21 form $\Sigma C_i^T U_i T_i$ $(3J \times J)$

4.22 form $\Sigma C_i^T U_i \dot{T}_i$ * $(3J \times J)$

4.23 form $\Sigma C_i^T U_i C_i$ * $(3J \times 3J)$

4.24 form $\Sigma C_i^T U_i C_i$ * $(3J \times 3J)$

* indicates that individual matrices are formed by adding to proper locations in matrix V initialized above.

4.30 end of do loop on i

5. Invert matrix $V \rightarrow V^{-1}$ $(6J \times 6J)$

6. correction vector $\delta_p = V^{-1} \hat{\delta} Z_1$ $(6J \times 1)$

7. start do loop on $i = 2, K$

7.1 form B_i and save

7.2 form B_i^T

7.3 product $B_i^T B_i$

7.4 sum $B_i^T B_i + \sigma^2 W_q^i$

7.5 invert $(B_i^T B_i + \sigma^2 W_q^i)^{-1}$

7.6 form vector $[-C_i \;\; I \;\; T_i \;\; \dot{T}_i] \begin{bmatrix} \delta_p \end{bmatrix}$ $(J \times 1)$

7.7 product $-B_i^T \times$ vector $\rightarrow$ new vector 3×1

7.8 product $(B_i^T B_i + \sigma^2 W_q^i)^{-1} \times$ new vector 3×1

7.9 $\delta q_i = \hat{\delta} Z_{2i}$ - last vector 3×1

7.10 end do loop on i

8. form new estimate of station vector $= P - \delta_p$

9. form new estimate of aircraft vector $Q = Q - \delta_q$

3. PROVISION FOR LOST DATA

In the LRPDS problem it is possible that during the course of the flight terrain or aircraft maneuvers will shadow transmission between the aircraft and any of the ground stations. This will result in loss of range change measurements during times when the ground station is shadowed. Since the data loss may occur at different times for different stations it is necessary to make provision for an arbitrary loss of data for each station at each aircraft

sampling time. The method of handling the loss of data must satisfy three criteria: 1) The method should allow the maximum utilization of the data collected so as to maintain the quality of positioning. 2) The method should not destroy the highly structured form of matrices involved so that full advantage of the structure can be taken in the computational procedure. 3) It is also necessary to retain the ability to provide a figure of merit for the resulting station locations determined by the systems which reflects the effects of the lost data.

The approach taken to provide for lost data can best be visualized by a simplified example. Suppose that a linear least squares estimate is required of the n dimensional vector X from m measurements which constitute the vector Z. The observation equations constitute the rows of a matrix H where dimensions are $m \times n$. The matrix equation relating X and Z is thus

$$HX = Z.$$

The solution vector $\hat{X}$ then satisfies the normal equations

$$H^T H\hat{X} = H^T Z.$$

If in the measurement procedure some z_k (or set of z_k) is lost or considered unacceptable there are two choices of how to handle the data reduction problem. First, the row dimension of the matrix H may be appropriately decreased and the measurements deleted from the vector Z. Second, a zero row vector may be inserted into H at each location of missing data and a zero inserted in Z corresponding to the missing data points.

The second approach has the virtue of not disrupting any of the structure of H so that a fixed data reduction procedure will still accomplish the desired result. In order to accomplish this deletion of rows and data points in an organized fashion define an $m \times m$ diagonal matrix S which has 1 or 0 entries as the particular measurement is present or missing. Then the relationship between X and Z becomes

$$SHX = SZ .$$

The solution $\hat{X}$ then satisfies the equation

I is $J \times J$ identity matrix

T_i is $J \times J$ diagonal matrix with entries t_i

$\hat{T}_i$ is $J \times J$ diagonal with entries $t_i^2/2$

The vectors required are given by:

$$\delta Z_1 = C^T \delta R + \sigma^2 W_p \dot{\delta} p$$

$$\delta Z_2 = B^T \delta R + \sigma^2 W_q \dot{\delta} q$$

$$\hat{\delta} Z_2 = (B^T B + \sigma^2 W_q)^{-1} \delta Z_2$$

$$\delta p = V^{-1}(\delta Z_1 - C^T B \delta Z_2)$$

$$\delta q = \hat{\delta} Z_2 - (B^T B + \sigma^2 W_q)^{-1} B^T C \delta p \quad .$$

The vector δR may be partitioned into K-1 vectors each J in size,

$$\delta R = \begin{bmatrix} \delta r_2 \\ \cdot \\ \cdot \\ \cdot \\ \delta r_k \end{bmatrix} \quad J(K-1) \times 1 \qquad \delta r_i \equiv \begin{bmatrix} \delta r_{1i} \\ \delta r_{2i} \\ \cdot \\ \cdot \\ \cdot \\ \delta r_{Ji} \end{bmatrix} \quad J \times 1 \quad .$$

The vector $\delta q = \begin{bmatrix} \delta q_{12} \\ \delta q_{22} \\ \delta q_{32} \\ \cdot \\ \cdot \\ \cdot \\ \delta q_{1K} \\ \delta q_{2K} \\ \delta q_{3K} \end{bmatrix} \quad 3(K-1) \times 1 \quad .$

$$V = \left| \sigma^2 W_p + C^T \left[I - B\,(B^T B + \sigma^2 W_q)^{-1} B^T \right] C \right|$$

$$\delta p = V^{-1}(\delta Z_1 - C^T B \hat{\delta Z_2})$$

and

$$\delta p = \hat{\delta} Z_2 - (B^T B + \sigma_j^2 W_q)^{-1}\, B^T C \delta p \,,$$

with

$$\delta Z_1 = C^T \delta R + \sigma^2 W_p \dot{\delta} p$$

$$\delta Z_2 = B^T \delta R + \sigma^2 W_q \dot{\delta} q$$

$$\hat{\delta} Z_2 = (B^T B + \sigma^2 W_q)^{-1}\, \delta Z_2$$

The matrix V which must be constructed is defined as

$$V = C^T \left[I - B\,(B^T B + \sigma^2 W_q)^{-1} B^T \right] C + \sigma^2 W_p \,.$$

Since B is block diagonal and $\sigma^2 W_q$ is diagonal

$$I - B\,(B^T B + \sigma^2 W_q)^{-1}\, B^T = \begin{bmatrix} I - B\,\left(B^T B_2 + \sigma^2 W_q^2\right)^{-1} B_2^T & & \\ & \ddots & \\ & & I - B_K (B_K^T B_K + \sigma^2 W_q^K)^{-1} B^T \end{bmatrix}$$

$$\begin{bmatrix} U_2 & & 0 \\ & \ddots & \\ 0 & & U_K \end{bmatrix}$$

where $U_i = I - B_i\,(B_i^T + \sigma^2 W_q^i)^{-1}\, B_i^T$.

Then the symmetric matrix V is given by

$$V = \begin{bmatrix} \sigma^2 W_P^S + \sum_{i=2}^{K} C_i^T U_i C_i & -\sum_{2}^{K} C_i^T U_i & \sum_{2}^{K} C_i^T U_i T_i & \Sigma C_i^T U_i \dot{T}_i \\ & \sum_{2}^{K} U_i + \sigma^2 W_p^{RO} & -\Sigma U_i T_i & -\Sigma U_i \dot{T}_i \\ & & \Sigma T_i^T U_i T_i + \sigma^2 W_p^a & \Sigma T_i^T U_i \dot{T} \\ & & & \Sigma T_i^T U_i T + \sigma^2 W_p^b \end{bmatrix}$$

Where W_P^S is the diagonal matrix of station location constraints

W_p^{RO} is the diagonal initial range constraints

W_p^a is the freq. offset constraint

W_p^b is the freq. drift constraint

The matrix C^T is given by

$$C^T \equiv \begin{bmatrix} -C_2^T & -C_3^T & \cdots & -C_K^T \\ I & I & & I \\ -T_2^T & -T_3^T & \cdots & -T_K^T \\ -\dot{T}_2^T & -\dot{T}_3^T & \cdots & -\dot{T}_K^T \end{bmatrix}$$

$$C_i^T \equiv \begin{bmatrix} -(q_{1i} - p_{11})/r_{1i} & & & \\ -(q_{2i} - p_{21})/r_{1i} & & & \\ -(q_{3i} - p_{31})/r_{1i} & & & \\ & -(q_{1i} - p_{12})/r_{2i} & & \\ & -(q_{2i} - p_{22})/r_{2i} & & \\ & -(q_{3i} - p_{32})/r_{2i} & & \\ & & \ddots & \\ & & & -(q_{1i} - p_{1J})/r_{Ji} \\ & & & -(q_{2i} - p_{2J})/r_{Ji} \\ & & & -(q_{3i} - p_{3J})/r_{Ji} \end{bmatrix}_{3J \times J}$$

$$H^T S^T S H \hat{X} = H^T S^T S Z.$$

Because S is diagonal and contains only ones and zeros

$$S^T S = S$$

so that,

$$H^T S H \hat{X} = H^T S Z$$

From this simplified example it is evident that the way to include provision for lost data points is to carry the effects of the matrix S through the entire data reduction procedure and delete those entries which would be multiplied by the zero entries in S.

To relate the method of handling lost data directly to the LRPDS problem the development of the equations presented previously can be modified by replacing the matrices C and B with matrices SC and SB. The δR vector is replaced with a vector $S\delta R$. The equations to be solved within the iterative portion of the solution method may then be restated as:

$$\begin{bmatrix} C^T S W_1 S C + W_p & C^T S W_1 S B \\ B^T S W_1 S C & B^T S W_1 S B + W_q \end{bmatrix} \begin{bmatrix} \delta_p \\ \delta_q \end{bmatrix} \begin{bmatrix} C^T S W_1 S \\ B^T S W_1 S \end{bmatrix} \delta R + \begin{bmatrix} W_p \dot{\delta}_p \\ W_q \dot{\delta}_q \end{bmatrix}$$

Where all of the symbols are as previously defined.

The primary influence of the inclusion of the lost data matrix S appears in the expression for the matrix V which is the coefficient matrix in the set of normal equations for the δ_p vector.

The matrix V now becomes

$$V = \begin{bmatrix} \sigma^2 W_p^S + \sum_{i=2}^{K} C_i^T \dot{U}_i C_i & -\Sigma C_i^T \dot{U}_i & \Sigma C_i^T \dot{U}_i T_i & \Sigma C_i^T \dot{U}_i \dot{T}_i & \Sigma C_i^T \dot{U}_i R_i \\ & \sigma^2 W_p^{RO} + \Sigma \dot{U}_i & -\Sigma \dot{U}_i T_i & -\Sigma \dot{U}_i \dot{T}_i & -\Sigma \dot{U}_i R_i \\ & & \sigma^2 W_p^a + \Sigma T_i^T \dot{U}_i T_i & \Sigma T_i^T \dot{U}_i \dot{T}_i & \Sigma T_i^T \dot{U}_i R_i \\ & & & \sigma^2 W_p^b + \Sigma \dot{T}_i^T \dot{U}_i \dot{T}_i & \Sigma \dot{T}_i \dot{U}_i R_i \\ & & & & \sigma^2 W_p^p + \Sigma R_i^T \dot{U}_i R_i \\ & & & & \end{bmatrix}$$

Where $\dot{U}_i \equiv S_i \, [I - B_i^T S_i (B_i^T S_i B_i + \sigma^2 W_q^i)^{-1} \, S_i B_i] S_i$

S_i is the i^{th} $J \times J$ block (along the diagonal) of S, the lost data matrix.

Another impact lost data has on the overall reduction problem is that if the number of ground stations visible from each aircraft location falls below some minimum value the solution for that aircraft location will either be impossible or so weak as to not be useful. If this happens then that aircraft location (or set of locations) must be excluded from the solution.

The minimum number of visible ground stations allowable from each aircraft location is a function of how many coordinates of the aircraft position are being estimated at once. From geometric consideration, it is evident that for two coordinates being estimated (x, y) then there must be observation available from three or more non-colinear ground stations to resolve the possible ambiguity in the solution. In a similar way, if three coordinates (x, y, z) are being estimated, then observation from four or more non-coplanar stations must be available. Although the use of four observations does not guarantee that the stations observed are not coplanar, it is certain that if only three stations are used, they will be coplanar (since three points uniquely define a plane). Without these constraints on the number of stations visible it is possible for the iterative solution to drive any aircraft point not having at least the minimum to an incorrect solution point corresponding to the wrong member of an ambiguous pair of solutions.

4. REQUIREMENTS FOR SELECTABLE ESTIMATION OF PARAMETERS

The formulation of the data reduction procedure up to this point has assumed that all of the parameters mentioned[i.e. $3J$ station locations, J initial ranges, J frequency offsets, J frequency drifts, and 3 $(k-1)$ aircraft location parameters] are required to be estimated. Although this is true in the final stages of the adjustment, it is not true in the first few iterations to bring the parameters of interest into the range for final adjustment. The total data reduction program must therefore have provisions for selecting those parameters which are to be estimated at each stage of the data reduction procedure.

It is necessary to restrict the estimation to aircraft x, y only for the first few iterations in order to bring the relatively unknown flight path parameters close enough to the true values to perform the full adjustment on all parameters. This means that for the aircraft portion of the problem only two position parameters are to be estimated rather than three. In a similar way, the ground station parameters to be estimated will vary depending on the degree of certainty of the solution. It, therefore, becomes necessary to provide for a flexible selection of the parameters to be estimated for both the aircraft locations and the ground station parameters.

AIRCRAFT PARAMETER SELECTION

For the aircraft locations there are only three choices to be considered:

1) Estimate aircraft x, y and z
2) Estimate aircraft x, y
3) Do not estimate aircraft locations.

GROUND STATION PARAMETER SELECTION

For the ground station parameters the number of choices is more complex.

Ground Station Position Coordinates

1. Estimate all ground station position parameters - x, y, z
2. Estimate ground stations x, y only
3. Do not estimate ground station positions

Ground Station Initial Range - a_{oj}

The estimation of the a_{oj} term for each ground station is required for all circumstances.

Ground Station Frequency Offset - a_{1j}

The ground station frequency offset, a_{1j}, may or may not be required depending on the level of accuracy required at a given stage of the data reduction.

Ground Station Frequency Drift Rate - a_{2j}

The frequency drift rate, a_{2j}, must be selectable.

5. DATA REDUCTION FLOW DIAGRAM

The overall requirements for the data reduction and the equations to be mechanized have been established by the preceding discussion. The outline of the data reduction procedure may now be formulated to include all of the provisions required.

In order to derive the flow diagram for the computation the following notation is used:

J - number of ground stations being processed

NG - number of ground station position coordinates to be estimated (2 or 3) (x, y or x, y, z)

IGC - control parameter (1 or 0)

IGC = 1 enables the estimation of the ground station positions

IGC = 0 disables the estimation of ground station position (p_{mj}; m = 1, NG; j = 1, J)

IA1 - control parameter (1 or 0)

IA1 = 1 enables the estimation of ground station frequency offset (a_{1j}; j = 1, J)

IA2 - control parameter

IA2 = 1 enables the estimation of ground station frequency drift rate. (a_{2j}; j = 1, J)

K - total number of aircraft locations used

NA - number of aircraft position coordinates estimated (2 or 3) (x, y or x, y, z)

IAC - control parameter (1 or 0)

IAC = 1 enables the estimation of the aircraft location

IK(i) - control parameter

IK(i) = 1 enables the estimation of the i^{th} aircraft location

IK(i) is set to zero if the number of ground stations visible fails to satisfy the necessary criterion.

NSTA - minimum number of stations required to be visible from each aircraft location

NSTA = NA + 1

IDATA (j, i) - Control variable (1 or 0) which defines the diagonal elements of the lost data matrix S. The existence of a 1 at location j, i of the IDATA (j, i) control matrix denotes that the j^{th} station was visible from the i^{th} aircraft location and conversely if a zero exists.

IACS, IGCS - Control parameters (1 or 0)

IACS = 1 or IGCS = 1 denotes that one or more aircraft locations or ground station parameters have not satisfied the convergence criterion and hence another iteration of the problem is required. When all parameters have satisfied the convergence criteria then IACS and IGCS will be zero.

J1, J3, J4, J5 - indices of the location of various parts of the matrix V. The symmetric matrix V is organized in block form as shown below

V(J1, J1) NG•J × NG•J	V(J1, J3) NG•J × J	V(J1, J4) NG•J × J	V(J1, J5) NG•J × J
	V(J3, J3) J × J	V(J3, J4) J × J	V(J3, J5) J × J
		V(J4, J4) J × J	V(J4, J5) J × J
			V(J5, J5) J × J

The indices shown refer to the first row and column (upper, left hand corner) of each sub-matrix.

In a similar way the vector $\hat{\delta Z}_1$ is denoted by

$\hat{\delta Z}_1(J1)$	$NG \cdot J \times 1$
$\hat{\delta Z}_1(J3)$	$J \times 1$
$\hat{\delta Z}_1(J4)$	$J \times 1$
$\hat{\delta Z}_1(J5)$	$J \times 1$

to distinguish the various component parts of the vector.

In general

J1 - defines the location containing elements of the matrix (or vector) related to ground station position. (p_{mj})

J3 - defines the location related to initial range estimation. (a_{0j})

J4 - defines the location related to frequency offset. (a_{1j})

J5 - defines the location related to frequency drift rate (a_{2j})

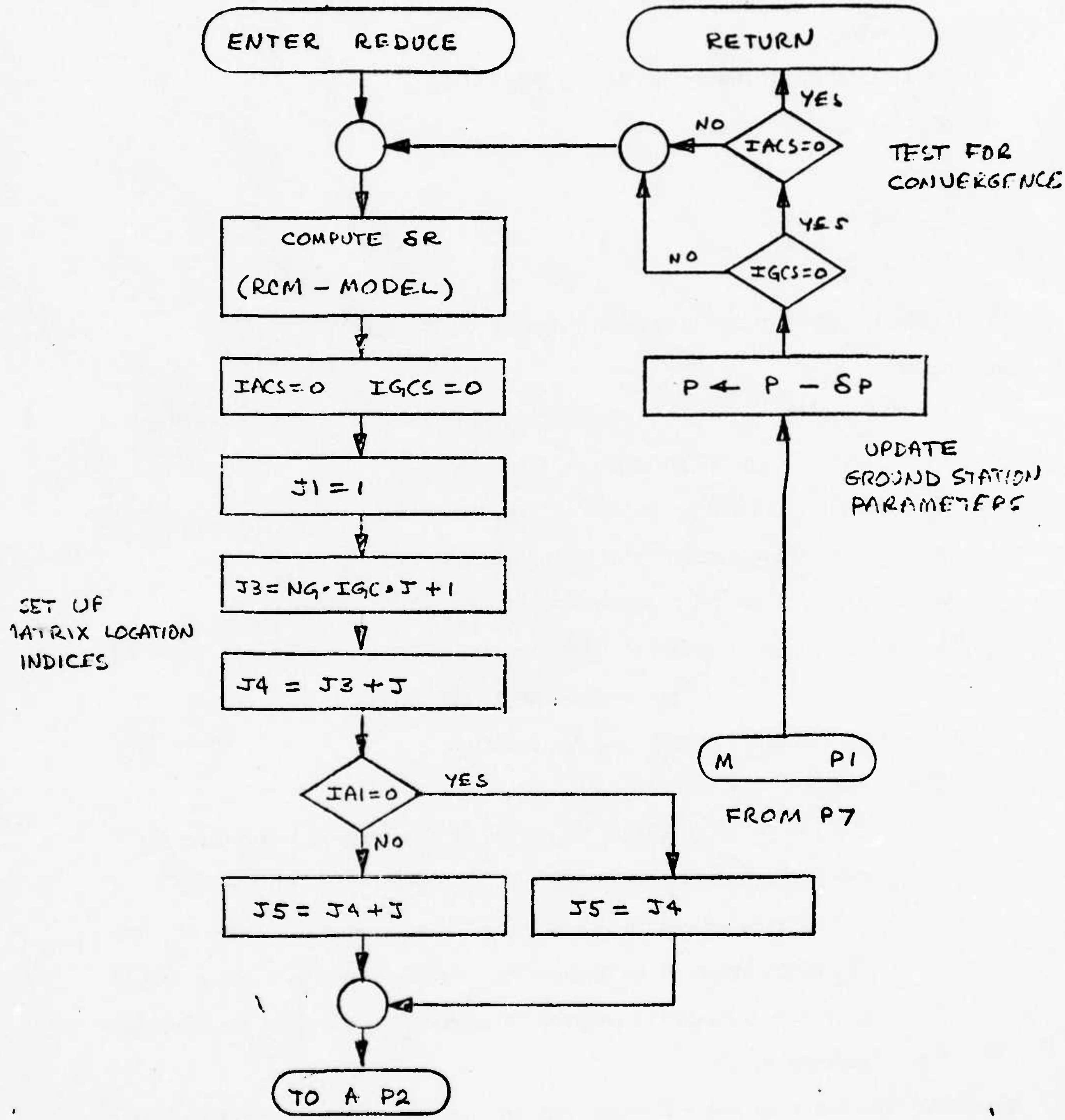
S1, S2, S3, S4, S6 - Refer to temporary matrix storage locations required in the evaluation of the matrix V.

DRP - is a temporary vector storage location

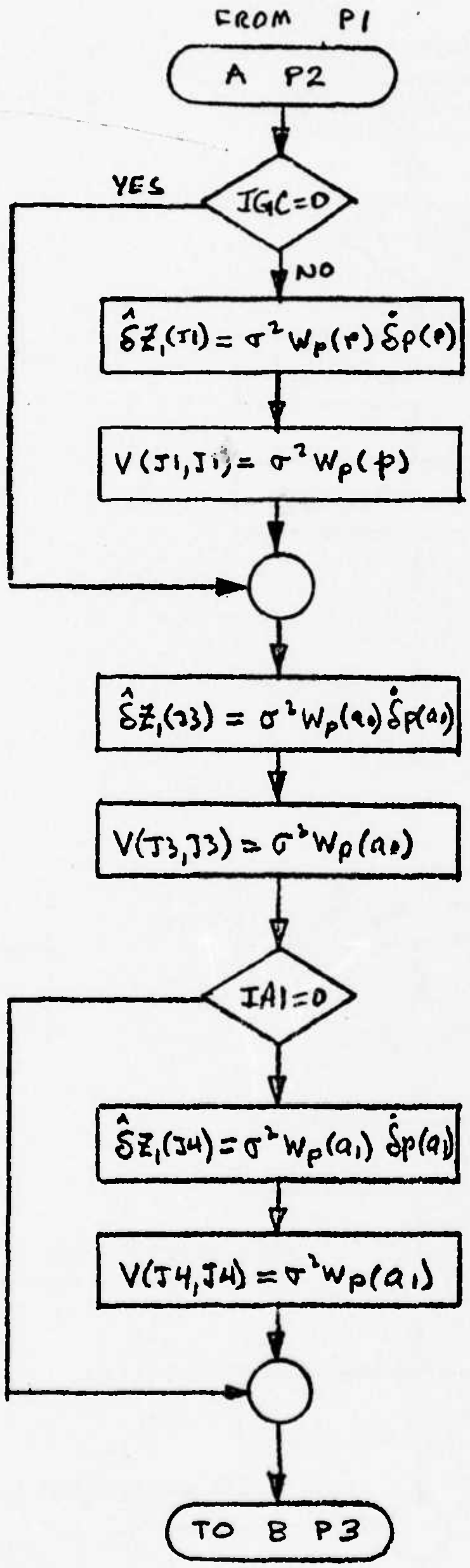
ITIME - control variable (1 or 0)

The use of ITIME allows a portion of the program to be used for two different purposes. When ITIME = 0 the path through the computation procedure yields the matrix V and the vectors $\hat{\delta Z}_1$ and $\hat{\delta Z}_2$ which are used to compute δp. ITIME is set to 1 and a second pass made through the program to compute the aircraft location correction δq.

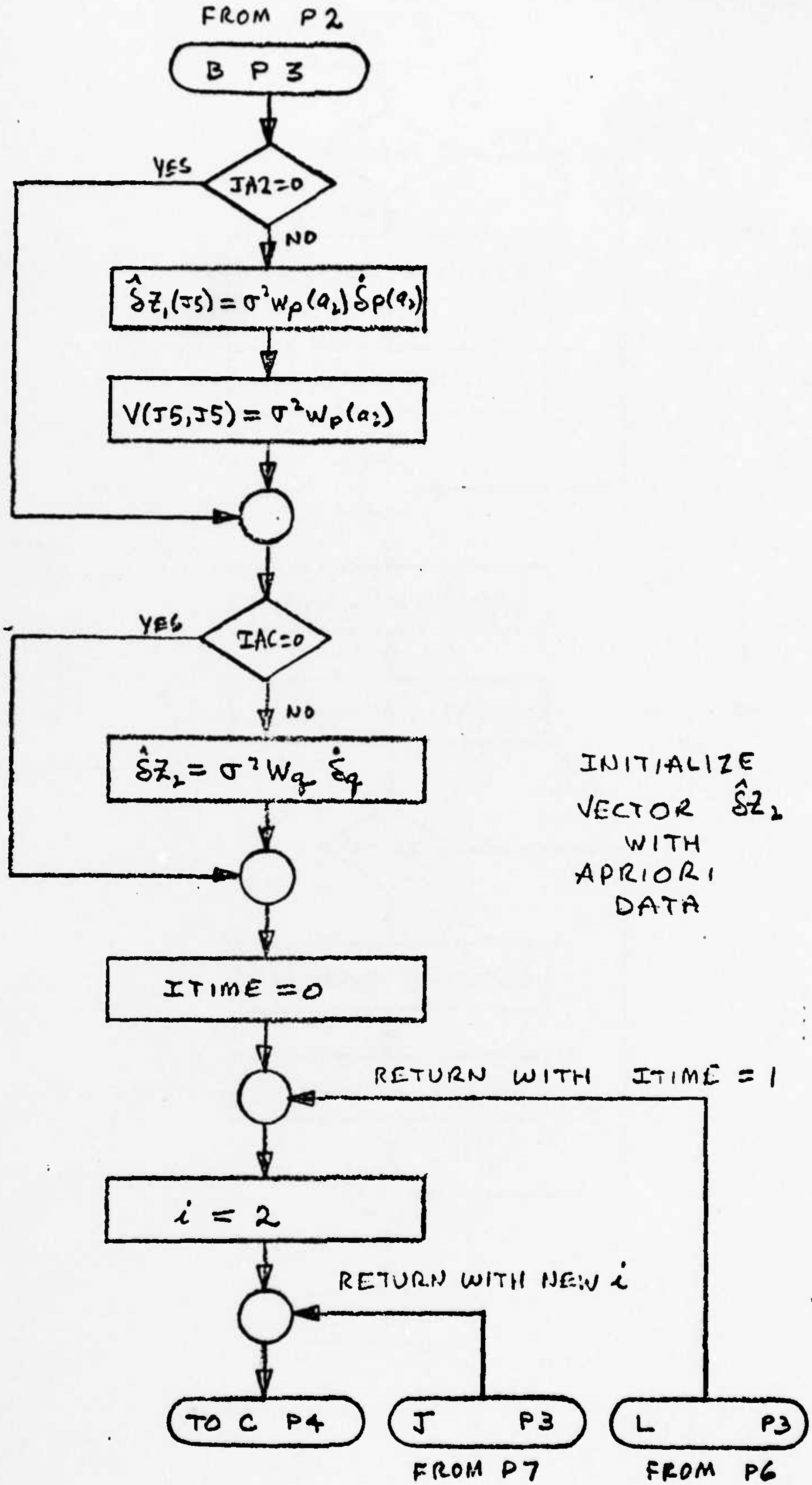
Notation: The notation $A \leftarrow A + B$ means that the new value of the variable A is determined by adding B to the old value of A. In most cases this operation could be written as $A_i = A_{i-1} + B_i$, but in order to reduce the notational requirements the form listed above was used.

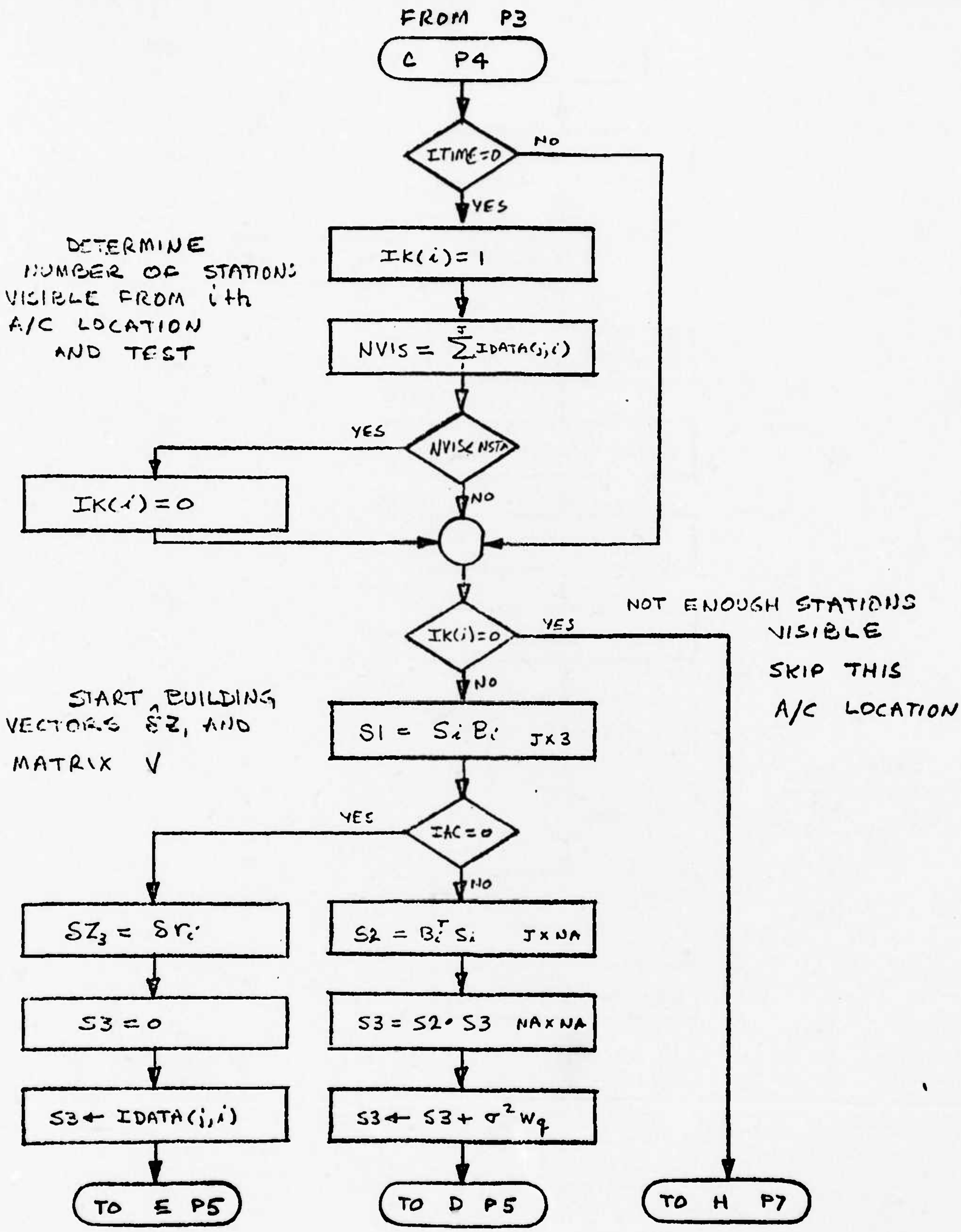


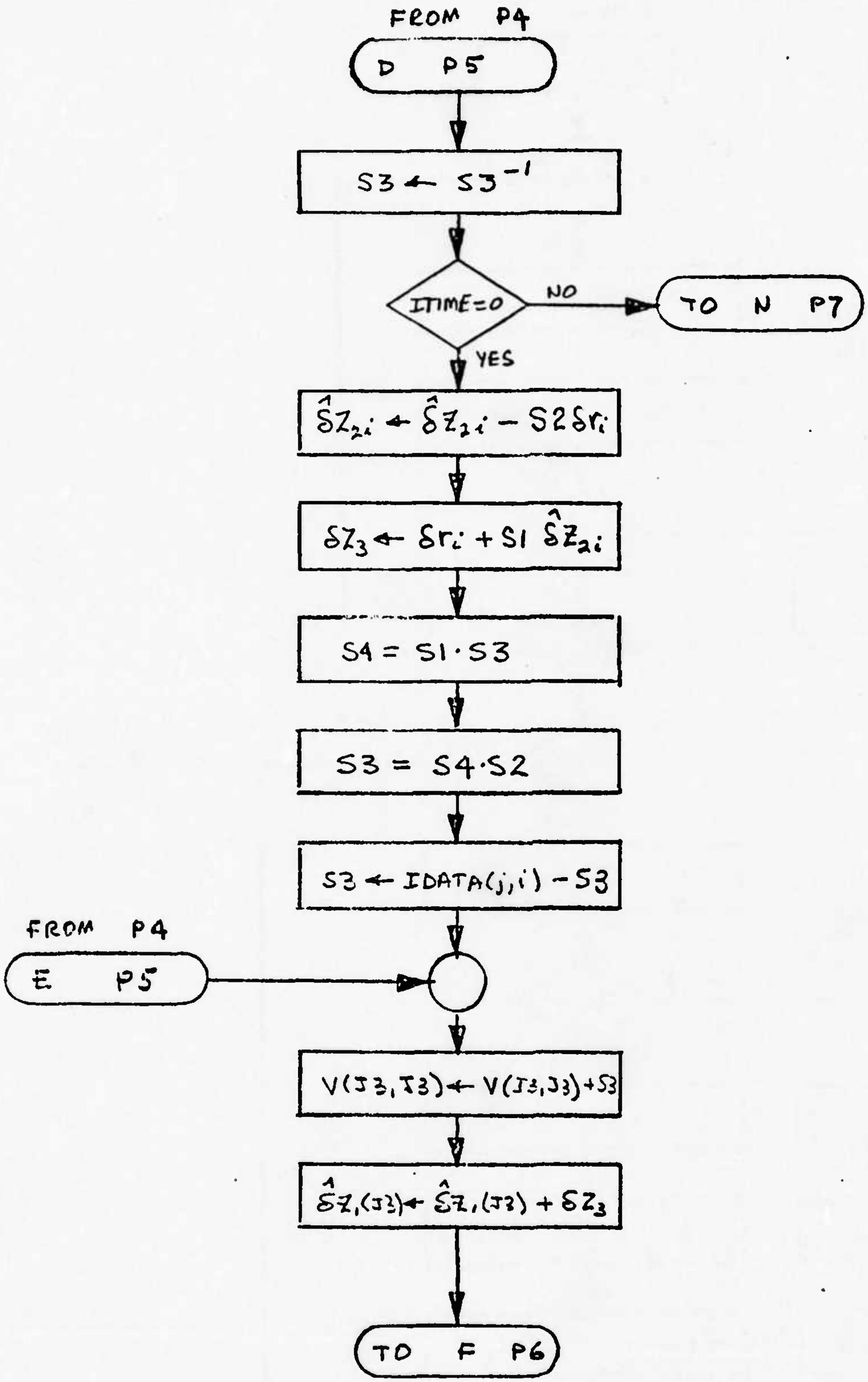
ENTER REDUCE
RETURN
YES
NO
IACS=0
TEST FOR CONVERGENCE
YES
NO
IGCS=0
COMPUTE δR
(RCM – MODEL)
IACS=0 IGCS=0
P ← P – δP
UPDATE GROUND STATION PARAMETERS
J1=1
J3=NG·IGC·J+1
SET OF MATRIX LOCATION INDICES
J4 = J3+J
M P1
IA1=0
YES
FROM P7
NO
J5= J4+J
J5 = J4
TO A P2



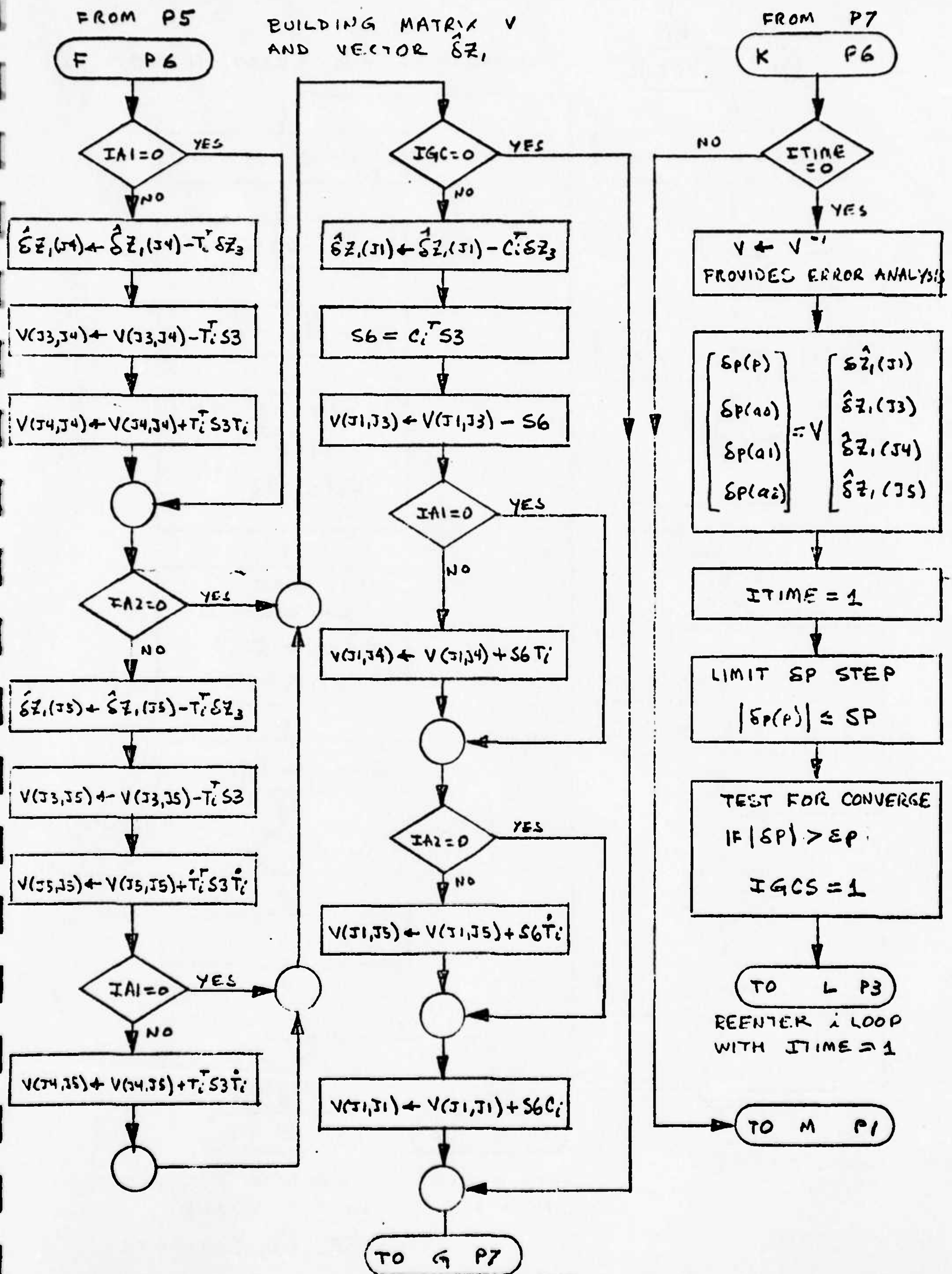
INITIALIZE
VECTOR $\hat{\delta}Z_1$
AND
MATRIX V
WITH
APRIORI DATA

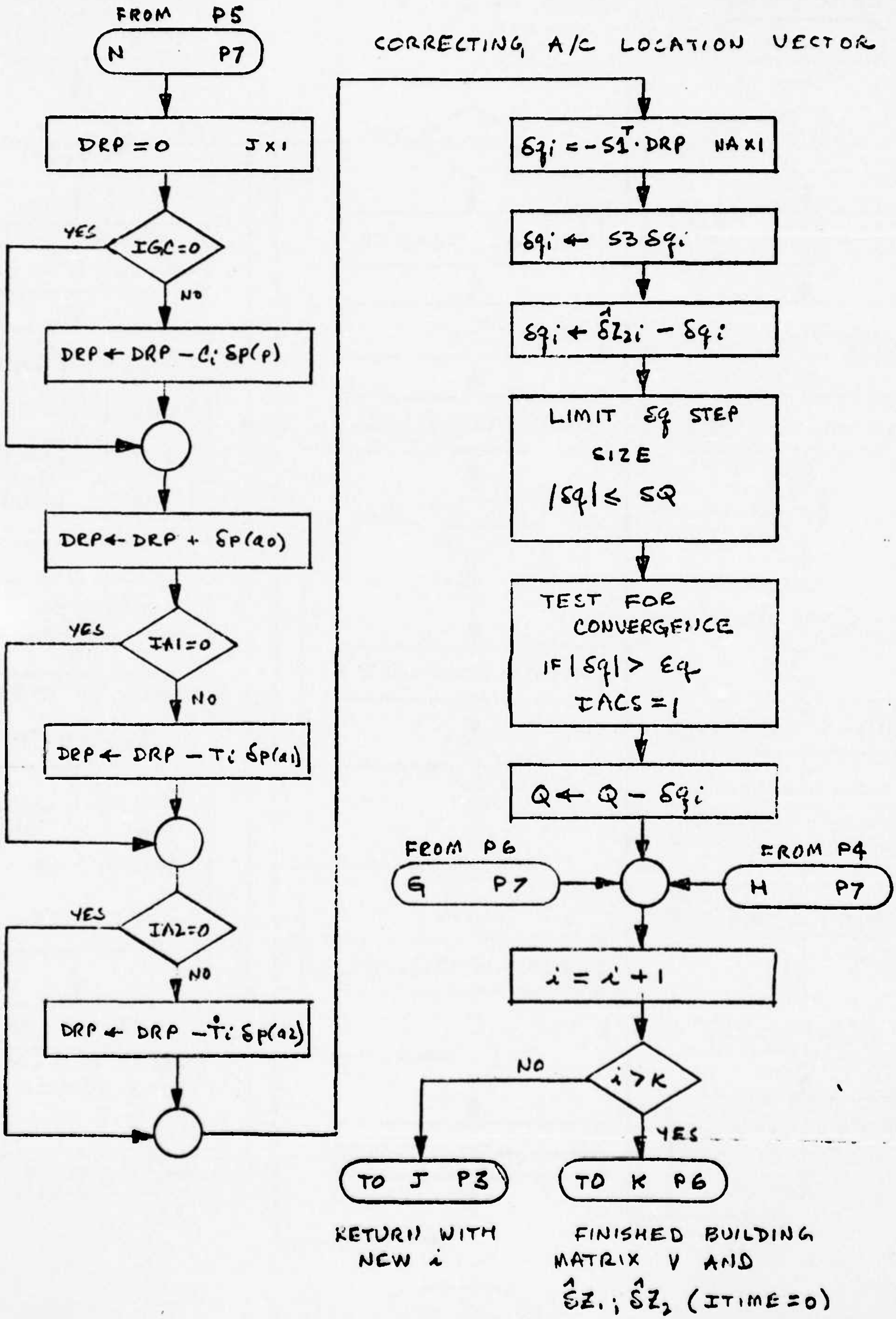

FROM P2
B P3
JA2=0
YES
NO
$\hat{\delta Z}_1(J5) = \sigma^2 W_p(a_2)\,\dot{\delta p}(a_2)$
$V(J5,J5) = \sigma^2 W_p(a_2)$
IAC=0
YES
NO
$\hat{\delta Z}_2 = \sigma^2 W_q\,\dot{\delta q}$
INITIALIZE VECTOR $\hat{\delta Z}_2$ WITH APRIORI DATA
ITIME = 0
RETURN WITH ITIME = 1
$i = 2$
RETURN WITH NEW i
TO C P4
J P3
L P3
FROM P7
FROM P6


FROM P3
C P4
ITIME=0
NO
YES
IK(i)=1
DETERMINE NUMBER OF STATIONS VISIBLE FROM ith A/C LOCATION AND TEST
NVIS = $\sum_{1}^{J}$ IDATA(j,i)
NVIS<NSTA
YES
NO
IK(i)=0
IK(i)=0
YES
NO
NOT ENOUGH STATIONS VISIBLE SKIP THIS A/C LOCATION
START BUILDING VECTORS $\hat{\delta Z}_1$ AND MATRIX V
S1 = $S_i B_i$ J×3
IAC=0
YES
NO
$SZ_3 = \delta r_i$
S3 = 0
S3 ← IDATA(j,i)
S2 = $B_i^T S_i$ J×NA
S3 = S2·S3 NA×NA
S3 ← S3 + $\sigma^2 W_q$
TO E P5
TO D P5
TO H P7



FROM P4
D P5
$S3 \leftarrow S3^{-1}$
ITIME=0
NO
TO N P7
YES
$\hat{\delta Z}_{2i} \leftarrow \hat{\delta Z}_{2i} - S2\,\delta r_i$
$\delta Z_3 \leftarrow \delta r_i + S1\,\hat{\delta Z}_{2i}$
$S4 = S1 \cdot S3$
$S3 = S4 \cdot S2$
$S3 \leftarrow IDATA(j,i) - S3$
FROM P4
E P5
$V(J3,J3) \leftarrow V(J3,J3) + S3$
$\hat{\delta Z}_1(J3) \leftarrow \hat{\delta Z}_1(J3) + \delta Z_3$
TO F P6


FROM P5
F P6
BUILDING MATRIX V AND VECTOR δẐ1
FROM P7
K P6
IA1=0
YES
NO
δẐ1(J4) ← δẐ1(J4) − Ti^T δZ3
V(J3,J4) ← V(J3,J4) − Ti^T S3
V(J4,J4) ← V(J4,J4) + Ti^T S3 Ti
IA2=0
YES
NO
δẐ1(J5) ← δẐ1(J5) − Ti^T δZ3
V(J3,J5) ← V(J3,J5) − Ti^T S3
V(J5,J5) ← V(J5,J5) + Ṫi^T S3 Ṫi
IA1=0
YES
NO
V(J4,J5) ← V(J4,J5) + Ti^T S3 Ṫi
IGC=0
YES
NO
δẐ1(J1) ← δẐ1(J1) − Ci^T δZ3
S6 = Ci^T S3
V(J1,J3) ← V(J1,J3) − S6
IA1=0
YES
NO
V(J1,J4) ← V(J1,J4) + S6 Ti
IA2=0
YES
NO
V(J1,J5) ← V(J1,J5) + S6 Ṫi
V(J1,J1) ← V(J1,J1) + S6 Ci
TO G P7
ITIME =0
NO
YES
V ← V^-1
PROVIDES ERROR ANALYSIS
[δp(P), δp(a0), δp(a1), δp(a2)] = V [δẐ1(J1), δẐ1(J3), δẐ1(J4), δẐ1(J5)]
ITIME = 1
LIMIT δP STEP
|δp(P)| ≤ SP
TEST FOR CONVERGE
IF |δP| > εP
IGCS = 1
TO L P3
REENTER i LOOP WITH ITIME = 1
TO M P1


CORRECTING A/C LOCATION VECTOR
FROM P5
N P7
DRP = 0 J x 1
IGC=0
YES
NO
DRP ← DRP − Ci δp(p)
DRP ← DRP + δp(a0)
IA1=0
YES
NO
DRP ← DRP − Ti δp(a1)
IA2=0
YES
NO
DRP ← DRP − Ṫi δp(a2)
δqi = −S1T · DRP NA x 1
δqi ← S3 δqi
δqi ← δ̂Z2i − δqi
LIMIT δq STEP SIZE
|δq| ≤ SQ
TEST FOR CONVERGENCE
IF |δq| > εq
IACS = 1
Q ← Q − δqi
FROM P6
G P7
FROM P4
H P7
i = i + 1
i > K
NO
YES
TO J P3
TO K P6
RETURN WITH NEW i
FINISHED BUILDING MATRIX V AND
δ̂Z1 ; δ̂Z2 (ITIME=0)

APPENDIX B

COORDINATE CONVERSION CALCULATIONS

1.0 INTRODUCTION

The requirements for the LRPDS program state that positional data input to and output from the computer terminal be in either Universal Transverse Mercator (UTM) or Geodetic Latitude and Longitude Coordinates (LAT-LONG). The nature of the data reduction problem is such that it is highly desirable to utilize a simple local X, Y, Z coordinate system thus avoiding many trig function calculations. The most direct way to approach this coordinate conversion problem is to convert all coordinates to lat-long and then from lat-long to the coordinate system desired. This method also allows for easy solution to the adjacent zone problem in overlap regions since conversion to Easting and Northing in each zone can be made from the lat-long position. Thus, four routines are required; namely, LAT-LONG to UTM, UTM to LAT-LONG, LAT-LONG to LOCAL, LOCAL to LAT-LONG.

2.0 THE SPHEROID

The accepted shape of the earth for mapping purposes is a spheroid generated by the revolution of an ellipse as shown in Figure 1.

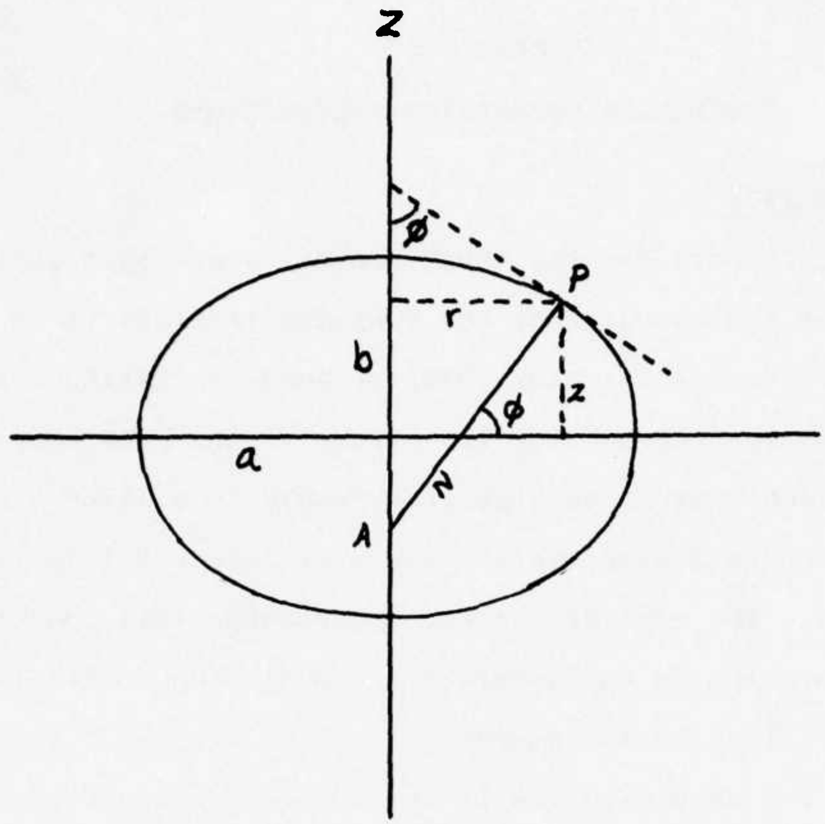


Figure 1. Meridian Ellipse of the Spheroid

In Figure 1, AP = N is the normal to the meridian ellipse at P(r, z). The semi-major axis is a and the geodetic latitude angle is ϕ. The equation for the ellipse is

$$r^2(1 - \epsilon^2) + z^2 = a^2\,(1 - \epsilon^2) \tag{1}$$

where

$$\frac{b^2}{a^2} = (1 - \epsilon^2) \tag{2}$$

and ϵ is the eccentricity, b is the semi minor axis of the ellipse. The spheroid specifications are usually given as the dimension of a and the inverse flattening 1/f. This factor is related to the other parameters as

$$\frac{1}{f} = \frac{a}{a - b} \tag{3}$$

or

$$b = a(1 - f) \tag{4}$$

and

$$\epsilon^2 = f(2. - f) \tag{5}$$

The list of spheroids in common usage are listed in Table 1.

Since the slope of the normal at P is the negative reciprocal of the slope of the tangent.

$$\tan \phi = - \frac{dr}{dz} = \frac{z}{r(1 - \epsilon^2)} \tag{6}$$

then

$$z = r(1 - \epsilon^2) \tan \phi = N(1 - \epsilon^2) \sin \phi \tag{7}$$

Substituting the value of z in terms of r we have

$$r = \frac{a \cos \phi}{\sqrt{1 - \epsilon^2 \sin^2 \phi}} = N \cos \phi \tag{8}$$

then

$$N = \frac{a}{\sqrt{1 - \epsilon^2 \sin^2 \phi}} \tag{9}$$

Name	Where Used	a (meters)	1/f
Airy	United Kingdom	6,377,563.396	299.324964
Australian National (IAU)	Australia	6,378,160.0	298.25
Bessel	East & Southeast Asia	6,377,397.155	299.152813
Clark 1858	Australia	6,378,293.645	294.26
Clark 1866	North America and Philippines	6,378,206.4	294.978698
Clark 1880	South Africa	6,378,249.145	293.465
Everest *	India	6,377,276.3452	300.8017
Fisher *	Southeast Asia	6,378,155.0	298.3
International	Other Areas	6,378,388.0	297.0
Krasovskii 1940	USSR and Eastern Europe	6,378,245.0	298.3

* The Fisher is tentatively scheduled to replace the Everest.

Table 1. Spheroid Parameters in Terms of Semi-Major Axis (a) and Inverse Flattening (1/f)

The radius of curvature of the meridian ellipse is given by

$$R = \left| \frac{a(1 - \epsilon^2)}{(1 - \epsilon^2 \sin^2 \phi)^{3/2}} \right| \tag{10}$$

In Figure 2 the ellipse has been revolved about its minor axis through an angle λ with the point P moving to P^1. In the X, Y, Z coordinate system, we have

$$y = r \sin \lambda = N \cos \phi \sin \lambda \tag{11}$$

$$x = r \cos \lambda = N \cos \phi \cos \lambda \tag{12}$$

$$z = N (1 - \epsilon^2) \sin \phi \tag{13}$$

$$\frac{x^2 + y^2}{a^2} + \frac{z^2}{b^2} = 1 \tag{14}$$

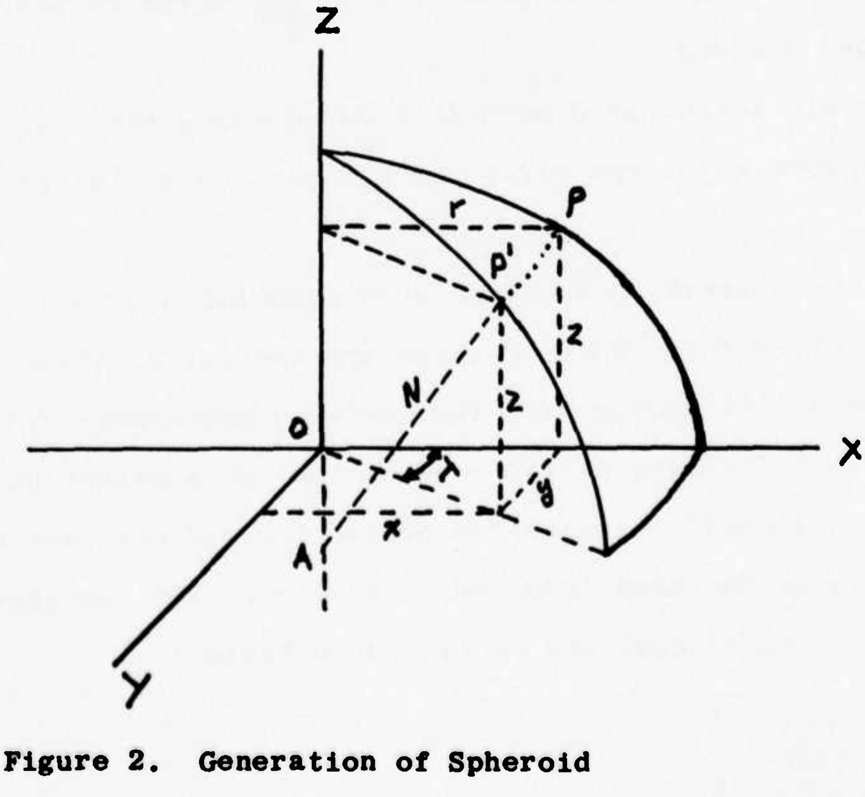


Figure 2. Generation of Spheroid

3.0 THE UNIVERSAL TRANSVERSE MERCATOR GRID AND PROJECTION (UTM)

The transverse Mercator projection is a conformal projection in that the angles measured on the projection or computed from the grid coordinates closely approximate their true values as well as the local scale factor at any point is the same in all directions. If we consider that a Mercator projection is similar to a projection upon a cylinder encasing the earth, the orientation of the cylinder axis for a transverse projection would be in the equatorial plane with the cylinder tangent to the earth at the central meridian of the map projection.

There are 60 transverse Mercator zones each 6° in width extending north to 84° and south to 80°. Zone number one lies between 180° and 174° west longitude. The zones are numbered consecutively from west to east. A 50 mile overlap provision is provided for at each zone boundry.

A scale factor of 0.9996 introduced along the central meridian of each zone gives the effect of a secant condition in the geometric sense.

The zone contains a metric grid superimposed upon it with a 500,000 meter false Easting along the central meridian, a zero meter Northing at the equator for the Northern Hemisphere and a 10,000,000 meter false Northing at the equator for the Southern Hemisphere.

The ellipsoid on which the projection and grid are based depends upon the area involved. The Clarke 1866 is used in North America. Other areas are as listed in Table 1.

3.1 UTM GRID FROM LAT-LONG COORDINATES

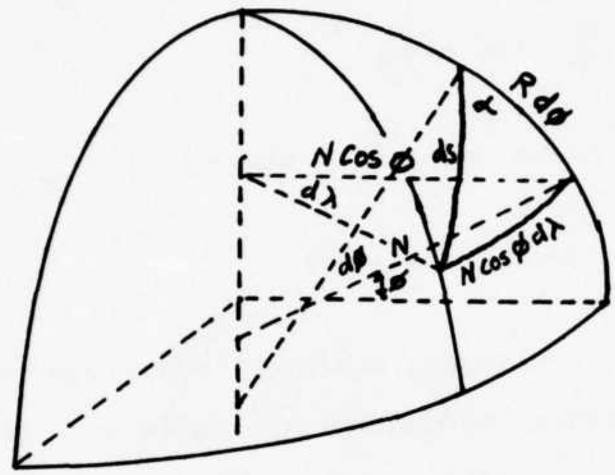


Figure 3. The Linear Element of the Spheroid is Obtained from A Differential Right Triangle

The transverse Mercator projection is a conformal mapping of the spheroid onto a plane such that a rhumb line intersects each meridian at a constant angle. From Figure 3, we have

$$\tan \alpha = \frac{N \cos \phi \, d\lambda}{r d\phi} \tag{15}$$

or

$$d\lambda = \tan \alpha \cdot \frac{R}{N} \sec \phi \, d\phi \tag{16}$$

Setting α equal to a constant the integral curves are

$$\lambda - \lambda_o = \tau \tan \alpha \tag{17}$$

where τ , the isometric latitude, is given by

$$\tau = \int_o^{\phi} \frac{R}{N} \sec \phi \, d\phi \tag{18}$$

now in mapping the z plane onto the w plane,

$$w = x + iy = f(z) = f(\lambda + i\,\tau) \tag{19}$$

The requirement for a transverse Mercator projection is that the scale shall be true along the central map meridian. Hence when $\lambda = 0$ we must have $x = 0$ and from (18) and (19) we must then have

$$iy = f(i\tau) = i\,S_{\phi} \tag{20}$$

where s_{ϕ} is the arc length along the elliptic meridian of the spheroid from the Equator to latitude ϕ.

$$S_{\phi} = \int_o^{\phi} R d\phi \tag{21}$$

and from (18) we have

$$R d\phi = N \cos \phi \, d\tau \tag{22}$$

So that

$$S_{\phi} = \int_o^{\phi} N \cos \phi \, d\tau = f(\tau) \tag{23}$$

If we expand $x + iy = f(\lambda + i\tau)$ about the point $z = i\tau$ we obtain

$$
\begin{aligned}
x + iy = f(\lambda + i\tau) &= f(i\tau) + \lambda f'(i\tau) + \frac{\lambda^2}{2!} f''(i\tau) \\
&+ \frac{\lambda^3}{3!} f''' (i\tau) + \cdots\cdots\cdots \\
&+ \frac{\lambda^{m'}}{m!} f^{R}(i\tau) + \cdots\cdots + \frac{\lambda^8}{8!} f^{v^{iii}}(i\tau) + \cdots
\end{aligned}
\qquad (24)
$$

now from (20) and (23) it is seen that

$$f(i\tau) = iS_{\phi} = if(\tau) \qquad (25)$$

differentiating this expression and substituting into (24) we have

$$
\begin{aligned}
x + iy &= if(\tau) + \lambda f'(\tau) - \frac{\lambda^2}{2!} if''(\tau) - \frac{\lambda^3}{3!} f'''(\tau) \\
&+ \frac{\lambda^4}{4!} if^{iv}(\tau) \cdots\cdots\cdots \\
&+ \frac{\lambda^8}{8!} if^{viii}(\tau) + \cdots\cdots
\end{aligned}
\qquad (26)
$$

equating real and imaginary parts

$$
\begin{aligned}
x &= \lambda f'(\tau) - \frac{\lambda^3}{3!} f'''(\tau) + \frac{\lambda^5}{5!} f^{v}(\tau) - \frac{\lambda^7}{7!} f^{vii}(\tau) + \cdots \\
y &= f(\tau) - \frac{\lambda^2}{2!} f''(\tau) + \frac{\lambda^4}{4!} f^{iv}(\tau) - \frac{\lambda^6}{6!} f^{vi}(\tau) + \frac{\lambda^8}{8!} f^{viii}(\tau) \\
&+ \cdots\cdots
\end{aligned}
\qquad (27)
$$

Using the following derivatives and trig identities:

$$N' = (N - R) \tan\phi$$

$$R' = 3\frac{R}{N} (N - R) \tan\phi$$

$$\left(\frac{N}{R}\right)' = -\frac{2(N - R)}{R} \tan\phi$$

$$\frac{d\phi}{d\tau} = \frac{N}{R} \cos\phi$$

$$(N \cos\phi)' = -R \sin\phi$$

$$(N \sin\phi)' = \operatorname{Sec}\phi \, (N - R \sin^2\phi) = (R \cos\phi)/(1 - \epsilon^2)$$

$$2 \sin n\phi \cos\phi = \sin (n + 1)\phi + \sin (n - 1)\phi$$

$$2 \cos n\phi \cos\phi = \cos (n + 1)\phi + \cos (n - 1)\phi$$

$$2 \cos n\phi \sin\phi = \sin (n + 1)\phi - \sin (n - 1)\phi$$

$$2 \sin n\phi \sin\phi = \cos (n - 1)\phi - \cos (n + 1)\phi \qquad (28)$$

Setting $N/R = \sigma$ we have,

$$f'(\tau) = N \cos\phi$$

$$f''(\tau) = (N^1 \cos\phi - N \sin\phi)\frac{d\phi}{d\tau} = -\frac{N}{2} \sin 2\phi$$

$$f'''(\tau) = -\frac{N}{4}\left[(3\sigma - 1) \cos\phi + (\sigma + 1) \cos 3\phi\right]$$

$$f''''(\tau) = \frac{N}{8}\left[2(-1 + \sigma + 4\sigma^2) \sin 2\phi + (1 + \sigma + 4\sigma^2) \sin 4\phi\right]$$

$$f^{v} = \frac{N}{16}\left\{\begin{array}{l} 2(1 - 2\sigma + 13\sigma^2 - 4\sigma^3)\cos\phi \\ + (-3 + 2\sigma - 3\sigma^2 + 44\sigma^3)\cos 3\phi \\ + (1 + 2\sigma - 7\sigma^2 + 28\sigma^3)\cos 5\phi \end{array}\right\}$$

$$f^{vi} = -\frac{N}{32}\left\{\begin{array}{l} (5 - 6\sigma - 91\sigma^2 + 364\sigma^3 - 136\sigma^4)\sin 2\phi \\ + 4(-1 + \sigma^2 - 28\sigma^3 + 88\sigma^4)\sin 4\phi \\ + (1 + 2\sigma + 33\sigma^2 - 196\sigma^3 + 280\sigma^4)\sin 6\phi \end{array}\right\}$$

$$f^{vii} = -\frac{N}{16}\left\{\begin{array}{l} (-5 + 9\sigma - 279\sigma^2 + 1911\sigma^3 - 2044\sigma^4 + 680\sigma^5)\cos\phi \\ + (9 - 9\sigma + 267\sigma^2 - 2831\sigma^3 + 6076\sigma^4 - 2280\sigma^5)\cos 3\phi \\ + (-5 - 3\sigma + 97\sigma^2 - 293\sigma^3 - 1708\sigma^4 + 3592\sigma^5)\cos 5\phi \\ + (1 + 3\sigma - 85\sigma^2 + 1277\sigma^3 - 4116\sigma^4 + 3640\sigma^5)\cos 7\phi \end{array}\right\}$$

$$f^{viii}(\tau) = \frac{N}{128}\left\{\begin{array}{l} 2(-7 + 9\sigma + 819\sigma^2 - 12413\tau^3 + 36984\sigma^4 - \\ \quad 33648\sigma^5 + 10240\sigma^6)\sin 2\phi \\ + 2(7 - 3\sigma - 279\sigma^2 + 7243\sigma^3 - 38568\sigma^4 + \\ \quad 58512\sigma^5 - 20864\sigma^6)\sin 4\phi \\ + 6(-1 - \sigma - 91\sigma^2 + 1381c^3 - 2872\sigma^4 - \\ \quad 3344\sigma^5 + 7168\sigma^6)\sin 6\phi \\ + (1 + 3\sigma + 279\sigma^2 - 7235\sigma^3 + 44136\sigma^4 - \\ \quad 90384\sigma^5 + 58240\sigma^6)\sin 8\phi \end{array}\right\} \qquad (29)$$

Substituting (29) into (27) we have

$$\frac{X}{N} = \lambda \cos\phi + \frac{\lambda^3}{24}\left[(3\sigma - 1)\cos\phi + (\sigma + 1)\cos 3\phi\right]$$

$$+ \frac{\lambda^5}{1920}\Big[2(1 - 2\sigma + 13\sigma^2 - 4\sigma^3)\cos\phi$$

$$+ (-3 + 2\sigma - 3\sigma^2 + 44\sigma^3)\cos 3\phi$$

$$+ (1 + 2\sigma - 7\sigma^2 + 28\sigma^3)\cos 5\phi\Big]$$

$$+ \frac{\lambda^7}{322560}\left[\begin{array}{l} (-5 + 9\sigma - 279\sigma^2 + 1911\sigma^3 - 2044\sigma^4 + 680\sigma^5)\cos\phi \\ + (9 - 9\sigma + 267\sigma^2 - 2831\sigma^3 + 6076\sigma^4 - 2280\sigma^5)\cos 3\phi \\ + (-5 - 3\sigma + 97\sigma^2 - 293\sigma^3 - 1708\sigma^4 + 3592\sigma^5)\cos 5\phi \\ + (1 + 3\sigma - 85\sigma^2 + 1277\sigma^3 - 4116\sigma^4 + 3640\sigma^5)\cos 7\phi \end{array}\right]$$

$$\frac{Y}{N} = \frac{S_\phi}{N} + \frac{\lambda^2}{4}\sin 2\phi + \frac{\lambda^4}{192}\Big[2(-1 + \sigma + 4\sigma^2)\sin 2\phi$$

$$+ (1 + \sigma + 4\sigma^2)\sin 4\phi\Big]$$

$$+ \frac{\lambda^6}{23040}\left\{\begin{array}{l} (5 - 6\sigma - 91\sigma^2 + 364\sigma^3 - 136\sigma^4)\sin 2\phi \\ + 4(-1 + \sigma^2 - 28\sigma^3 + 88\sigma^4)\sin 4\phi \\ + (1 + 2\sigma + 33\sigma^2 - 196\sigma^3 + 280\sigma^4)\sin 6\phi \end{array}\right\}$$

$$
+ \frac{\lambda^8}{5160960} \left\{ \begin{aligned} & 2\,(-7 + 9\sigma + 819\sigma^2 - 12413\sigma^3 + 36984\sigma^4 \\ & \qquad - 33648\sigma^5 + 10240\sigma^6) \sin 2\phi \\ & +2\,(7 - 3\sigma - 279\sigma^2 + 7243\sigma^3 - 38568\sigma^4 \\ & \qquad + 58512\sigma^5 - 20864\sigma^6) \sin 4\phi \\ & +6\,(-1 - \sigma - 91\sigma^2 + 1381\sigma^3 - 2872\sigma^4 \\ & \qquad -3344\sigma^5 + 7168\sigma^6) \sin 6\phi \\ & + (1 + 3\sigma + 279\sigma^2 - 7235\sigma^3 + 44136\sigma^4 - 90384\sigma^5 \\ & \qquad + 58240\sigma^6) \sin 8\phi \end{aligned} \right. \tag{30}
$$

Setting

$$\sigma = \frac{N}{R} = 1 + \delta \cos^2 \phi \tag{31}$$

where

$$\delta = \frac{\epsilon^2}{1 - \epsilon^2} = \epsilon'^2 \tag{32}$$

and

$$\eta^2 = \delta \cos^2 \phi \tag{33}$$

$$t = \tan \phi \tag{34}$$

We may rewrite (30) as

$$\frac{X}{N} = \lambda \cos \phi + \frac{\lambda^3 \cos^3 \phi}{6} (1 - t^2 + \eta^2) + \frac{\lambda^5 \cos^5 \phi}{120} (5 - 18t^2$$

$$+ t^4 + 14\eta^2 - 58t^2\eta^2 + 13\eta^4 - 64t^2\eta^4$$

$$+ 4\eta^6 - 24t^2\eta^6) +$$

$$\frac{\lambda^7 \cos^7 \phi}{5040} \left\{ \begin{array}{l} 61 - 479t^2 + 179t^4 - t^6 + 331\eta^2 \\ - 3298\eta^2 t^2 + 1771\eta^2 t^4 + 715\eta^4 \\ -8655t^2\eta^4 + 6080t^4\eta^4 + 769\eta^6 \\ - 10964t^2\eta^6 + 9480t^4\eta^6 + 412\eta^8 \\ - 6760t^2\eta^8 + 6912t^4\eta^8 + 88\eta^{10} \\ - 1632t^2\eta^{10} + 1920t^4\eta^{10} \end{array} \right\} \qquad (35)$$

$$\frac{Y}{N} = \frac{S\phi}{N} + \frac{\lambda^2}{2} \sin\phi \cos\phi + \frac{\lambda^4}{24} \sin\phi \cos^3\phi \, (5 - t^2 + 9\eta^2 + 4\eta^4) +$$

$$\frac{\lambda^6}{720} \sin\phi \cos^5\phi \, (61 - 58t^2 + t^4 + 270\eta^2 - 330t^2\eta^2 + 445\eta^4 - 680t^2\eta^4 + 324\eta^6 - 600t^2\eta^6 + 88\eta^8 - 192t^2\eta^8) +$$

$$\frac{\lambda^8}{40320} \sin\phi \cos^7\phi \left\{ \begin{array}{l} 1385 - 3111t^2 + 543t^4 - t^6 + 10899\eta^2 \\ - 32802t^2\eta^2 + 9219t^4\eta^2 + 34419\eta^4 \\ - 129087t^2\eta^4 + 49644t^4\eta^4 + 56385\eta^6 \\ - 252084t^2\eta^6 + 121800t^4\eta^6 + 50856\eta^8 \\ - 263088t^2\eta^8 + 151872t^4\eta^8 + 24048\eta^{10} \\ - 140928t^2\eta^{10} + 94080t^4\eta^{10} + 4672\eta^{12} \\ - 30528t^2\eta^{12} + 23040t^4\eta^{12} \end{array} \right\} \qquad (36)$$

Arranging (35) and (36) to facilitate computation and setting $\lambda = \lambda - \lambda_o = \Delta\lambda$ as the longitude difference from the central meridian and dropping out small terms we have

$$\frac{X}{N} = \Delta\lambda \cos\phi + \frac{\Delta\lambda^3 \cos^3\phi}{6} (1 - t^2 + \eta^2) + \frac{\Delta\lambda^5 \cos^5\phi}{120} (5 - 18t^2$$

$$+ t^4 + 14\eta^2 - 58t^2\eta^2 + 13\eta^4 + 4\eta^6 - 64\eta^4 t^2$$

$$- 24\eta^6 t^2) + \frac{\Delta\lambda^7 \cos^7}{5040} (61 - 479t^2$$

$$+ 179t^4 - t^6) \tag{37}$$

$$\frac{Y}{N} = \frac{S_\phi}{N} + \frac{\Delta\lambda^2}{2} \sin\phi \cos\phi + \frac{\Delta\lambda^4}{24} \sin\phi \cos^3\phi (5 - t^2$$

$$+ 9\eta^2 + 4\eta^4) +$$

$$\frac{\Delta\lambda^6}{720} \sin\phi\cos^5\phi \left\{ \begin{array}{l} 61 - 58t^2 + t^4 + 270\eta^2 - 330t^2\eta^2 \\ + 445\eta^4 + 324\eta^6 - 680\eta^4 t^2 + 88\eta^8 \\ - 600\eta^6 t^2 - 192\eta^8 t^2 \end{array} \right\}$$

$$+ \frac{\Delta\lambda^8}{40320} \sin\phi \cos^7\phi (1385 - 3111t^2 + 543t^4 - t^6) \tag{38}$$

The first three terms of (37) correspond to the functions IV, V and B_5 given in the Army Tech Man TM 5-241-8. The first four terms correspond to the functions I, II, III, and A_6 of the same manual. However, the functions A_6 and B_5 of the manual are truncated versions of the terms shown above.

3.1.1 Meridian Arc Length from Equator

The meridian arc length S is defined in equation (21). Substituting the value of R from (10) into this equation, we have

$$S_\phi = \int_o^\phi a(1 - \epsilon^2)\,(1 - \epsilon^2 \sin^2 t)^{3/2}\,dt \tag{39}$$

This may be written as

$$S_\phi = a(1 - \epsilon^2)\;\Pi\,(\phi, -\epsilon^2, \epsilon) \tag{40}$$

where $\Pi(\phi, -\epsilon^2, \epsilon)$ is Lengendre's Normal Elliptic Integral of the third kind. Now

$$\Pi(\phi, -\epsilon^2, \epsilon) = \frac{1}{1 - \epsilon^2}\,(E\,(\phi, \epsilon) -$$

$$(1 - \epsilon^2 \sin^2 \phi)^{-1/2} \quad \epsilon^2 \sin\phi \cos\phi) \tag{41}$$

where $E\,(\phi, \epsilon)$ is the incomplete Elliptic Integral of the second kind.

A series expansion for S_ϕ is given in Jordan's Handbook of geodesy, Vol. III, first half. This expansion using all terms involving ϵ through the 10th power is

$$s_\phi = a\,(1 - \epsilon^2)\,\Big(C_a\phi - \frac{C_b}{2}\sin 2\phi + \frac{C_c}{4}\sin 4\phi$$

$$- \frac{C_d}{6}\sin 6\phi + \frac{C_e}{8}\sin 8\phi - \frac{C_f}{10}\sin 10\phi\Big) \qquad (42)$$

where

$$C_a = 1 + \frac{3}{2^2}\epsilon^2 + \frac{3^2 \cdot 5}{2^6}\epsilon^4 + \frac{5^2 \cdot 7}{2^8}\epsilon^6 + \frac{5^2 \cdot 7 \cdot 9}{2^{14}}\epsilon^8 + \frac{7^2 \cdot 9^2 \cdot 11}{2^{16}}\epsilon^{10}$$

$$C_b = \frac{3}{2^2}\epsilon^2 + \frac{3 \cdot 5}{2^4}\epsilon^4 + \frac{(3 \cdot 5 \cdot 7)5}{2^9}\epsilon^6 + \frac{(5 \cdot 7 \cdot 9)7}{2^{11}}\epsilon^8 + \frac{(3 \cdot 5 \cdot 7 \cdot 9 \cdot 11)7}{2^{16}}\epsilon^{10}$$

$$C_c = \frac{3 \cdot 5}{2^6}\epsilon^4 + \frac{3 \cdot 5 \cdot 7}{2^8}\epsilon^6 + \frac{(5 \cdot 7 \cdot 9)7}{2^{12}}\epsilon^8 + \frac{(3 \cdot 5 \cdot 7 \cdot 9 \cdot 11)}{2^{14}}\epsilon^{10}$$

$$C_d = \frac{5 \cdot 7}{2^9}\epsilon^6 + \frac{5 \cdot 7 \cdot 9}{2^{11}}\epsilon^8 + \frac{(5 \cdot 7 \cdot 9 \cdot 11)9}{2^{17}}\epsilon^{10}$$

$$C_e = \frac{5 \cdot 7 \cdot 9}{2^{14}}\epsilon^8 + \frac{5 \cdot 7 \cdot 9 \cdot 11}{2^{16}}\epsilon^{10}$$

$$C_f = \frac{7 \cdot 9 \cdot 11}{2^{17}}\epsilon^{10} \qquad (43)$$

3.1.2 Central Scale Factor

Since the local scale factor increases as a function of the distance from the central meridian, the UTM system has adopted a central scale factor of 0.9996 to equalize the scale errors across the zone width. This scale factor is the one used for this program. Two other scale factors are in use in other areas of the world, such as .9999 used in Canada and 1.0000 used in many European countries. The scale factor is most easily accommodated into the calculation by modifying the semi-major axis by the scale factor as

$$a' = k_o a \tag{44}$$

where a' is the value to be used in calculating the UTM coordinates and k_o is the central scale factor. The units of a used in these equations is in meters instead of the usual units of minutes on the Equator.

3.2 LAT-LONG COORDINATES FROM UTM GRID

Rewriting (19) as

$$\lambda + i\tau = F\,(x + iy) \tag{45}$$

Now when $x = 0$, $\lambda = 0$ and then $F(iy) = i$ from (22) and (23)

$$\tau = \int_o^{\phi} \frac{R\, d\phi}{N \cos \phi} \tag{46}$$

$$\frac{d\tau}{dS_\phi} = \frac{1}{N \cos \phi} \tag{47}$$

$$\frac{d\phi}{dS_\phi} = \frac{1}{R} \qquad (48)$$

Expanding F(X + iy) about the point iy

$$\lambda + i\tau = F(iy) + X F'(iy) + \frac{x^2}{2!} F''(iy) +$$

$$\ldots\ldots\ldots \frac{x^n}{n!} F^{n'}(iy) \qquad (49)$$

From $F(iy) = i\tau$, we have $F'(iy) = \tau'$, $F''(iy) = -i\tau''$,

$$F^{iii}(iy) = -\tau^{iii},\ F^{iv}(iy) = i\tau^{iv},\ \cdots\ F^{n'} = i(-i)^n \tau^{n'}$$

We have

$$\lambda + i\tau = i\tau_1 + x\tau_1' - \frac{x^2}{2!} i\tau_1'' - \frac{x^3}{3!} \tau^{iii} +$$

$$\ldots\ldots \frac{x^n}{n!} i(-i)^n \tau^{n'} + \ldots\ldots \qquad (50)$$

Equating real and imag terms

$$\lambda = x\tau_1' - \frac{x^3}{3!} \tau_1^{iii} + \frac{x^5}{5!} \tau_1^{v} -$$

$$\frac{x^7}{7!} \tau_1^{vii} + \ldots\ldots \qquad (51)$$

$$\tau = \tau_1 - \frac{x^2}{2!}\tau_1^{iii} + \frac{x^4}{4!}\tau_1^{iv} - \frac{x^6}{6!}\tau_1^{vi} + \frac{x^8}{8!}\tau_1^{viii} - \ldots\ldots$$

where the subscript one refers to the "footpoint" latitude of a given point of the projection as shown in Figure 4.

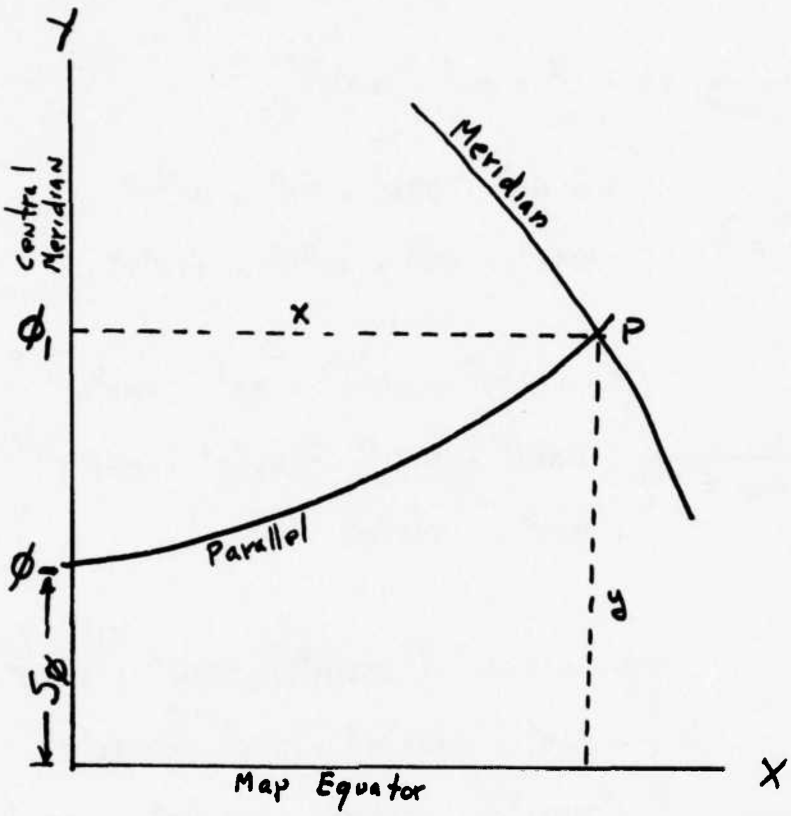


Figure 4. Footpoint Latitude ϕ_1, of Point P

from (47), (48) and (28)

$$\tau' = \frac{d\tau}{dS\phi} = \frac{1}{N \cos \phi} \tag{52}$$

$$\tau'' = \frac{(N \cos \phi)^1}{N^2 \cos^2 \phi} \quad \frac{d\phi}{dS} = \frac{\tan \phi}{N^2 \cos \phi} = \frac{t}{N^2 \cos \phi} \tag{53}$$

Similarily with $t = \tan \phi$, $N/R = 1 + \eta^2$ we have

$$\tau''' = \frac{1}{N^3 \cos \phi} \quad (1 + 2t^2 + \eta^2) \tag{54}$$

$$\tau^{iv} = \frac{t}{N^4 \cos\phi} (5 + \eta^2 + 6t^2 - 4\eta^4) \tag{55}$$

$$\tau^{v} = \frac{1}{N^5 \cos\phi} \left\{ \begin{array}{l} 5 + 6\eta^2 + 28t^2 - 3\eta^4 + 8t^2\eta^2 \\ + 24t^4 - 4\eta^6 + 4t^2\eta^4 + 24t^2\eta^6 \end{array} \right\} \tag{56}$$

$$\tau^{vi} = \frac{t}{N^6 \cos\phi} \left\{ \begin{array}{l} 61 + 46\eta^2 + 180t^2 - 3\eta^4 + 48t^2\eta^2 \\ + 120t^4 + 100\eta^6 - 36t^2\eta^4 - 96t^2\eta^6 \\ + 88\eta^8 - 192t^2\eta^8 \end{array} \right\} \tag{57}$$

$$\tau^{vii} = \frac{1}{N^7 \cos\phi} \left\{ \begin{array}{l} 61 + 662t^2 + 1320t^4 + 720t^6 + 107\eta^2 \\ + 43\eta^4 + 440t^2\eta^2 + 97\eta^6 - 234t^2\eta^4 \\ + 336t^4\eta^2 + 188\eta^8 - 772t^2\eta^6 - 192t^4\eta^4 \\ + 88\eta^{10} - 2392t^2\eta^8 + 408t^4\eta^6 + 1536t^4\eta^8 \\ - 1632t^2\eta^{10} + 1920t^4\eta^{10} \end{array} \right\} \tag{58}$$

$$\tau^{viii} = \frac{t}{N^8 \cos\phi} \left\{ \begin{array}{l} 1385 + 7266t^2 + 1731\eta^2 + 10920t^4 \\ +4416t^2\eta^2 - 573\eta^4 + 5040t^6 - 1830t^2\eta^4 \\ +2688t^4\eta^2 - 2927\eta^6 + 5052t^2\eta^6 \\ - 1536t^4\eta^4 - 8808\eta^8 + 27456t^2\eta^8 + 744t^4\eta^6 \\ - 11472\eta^{10} + 53952t^2\eta^{10} - 7872t^4\eta^8 \\ - 4672\eta^{12} + 30528t^2\eta^{12} - 24960t^4\eta^{10} \\ - 23040t^4\eta^{12} \end{array} \right\} \tag{59}$$

Placing these values into (51) we have

$$\Delta\lambda = \frac{1}{\cos\phi_1}\left\{\begin{array}{l} \dfrac{x}{N_1} - \dfrac{1}{6}\left(\dfrac{x}{N_1}\right)^3 (1 + 2t_1^{\,2} + \eta_1^{\,2}) \\[2ex] + \dfrac{1}{120}\left(\dfrac{x}{N_1}\right)^5 \left\{\begin{array}{l} 5 + 6\eta_1^{\,2} + 28t_1^{\,2} - 3\eta_1^{\,4} + 8t_1^{\,2}\eta_1^{\,2} \\ + 24t_1^{\,4} - 4\eta_1^{\,6} + 4t_1^{\,2}\eta_1^{\,4} + 24t_1^{\,2}\eta_1^{\,6} \end{array}\right\} \\[2ex] - \dfrac{1}{5040}\left(\dfrac{x}{N_1}\right)^7 \left\{\begin{array}{l} 61 + 662t_1^{\,2} + 1320t_1^{\,4} + 720t_1^{\,6} \\ + 107\eta_1^{\,2} + 43\eta_1^{\,4} + 440t_1^{\,2}\eta_1^{\,2} \\ + 97\eta_1^{\,6} - 234t_1^{\,2}\eta_1^{\,4} + 336t_1^{\,4}\eta_1^{\,2} \\ + 188\eta_1^{\,8} - 772t_1^{\,2}\eta_1^{\,6} - 192t_1^{\,4}\eta_1^{\,4} \\ + 1536t_1^{\,4}\eta_1^{\,8} - 1632t_1^{\,2}\eta_1^{\,10} \\ + 1920t_1^{\,4}\eta_1^{\,10} \end{array}\right\} \end{array}\right\} \qquad (60)$$

In the coefficient of $\left(\frac{x}{N_1}\right)^7$, all terms containing η, may be deleted without seriously effecting accuracy.

$$
\Delta\tau = \tau - \tau_1 = \frac{t_1}{\cos\phi_1}\left[-\frac{1}{2}\left(\frac{x}{N_1}\right)^2 + \frac{1}{24}\left(\frac{x}{N_1}\right)^4 (5 + \eta_1^{\,2} + 6t_1^{\,2} - 4\eta_1^{\,4}) \right.
$$

$$
- \frac{1}{720}\left(\frac{x}{N_1}\right)^6 \left[\begin{aligned} &61 + 46\eta_1^{\,2} + 180t_1^{\,2} - 3\eta_1^{\,4} \\ &+ 48\, t_1^{\,2}\eta_1^{\,2} + 120t_1^{\,4} + 100\eta_1^{\,6} \\ &- 36t_1^{\,2}\eta_1^{\,4} - 96t_1^{\,2}\eta_1^{\,6} + 88\eta_1^{\,8} \\ &- 192t_1^{\,2}\eta_1^{\,8} \end{aligned} \right]
$$

$$
\left. + \frac{1}{40320}\left(\frac{x}{N_1}\right)^8 \left[\begin{aligned} &1385 + 7266t_1^{\,2} + 1731\eta_1^{\,2} \\ &+ 10920t_1^{\,4} + 4416t_1^{\,2}\eta_1^{\,2} - 573\eta_1^{\,4} \\ &+ 5040t_1^{\,6} - 1830t_1^{\,2}\eta_1^{\,4} + 2688t_1^{\,4}\eta_1^{\,2} \\ &- 2927\eta_1^{\,6} + 5052t_1^{\,2}\eta_1^{\,6} - 1536t_1^{\,4}\eta_1^{\,4} \\ &- 8808\eta_1^{\,8} + 27456t_1^{\,2}\eta_1^{\,8} + 744t_1^{\,4}\eta_1^{\,6} \\ &- 11472\eta_1^{\,10} + 53952t_1^{\,2}\eta_1^{\,10} \\ &- 7872t_1^{\,4}\eta_1^{\,8} - 4672\eta_1^{\,12} + 30528t_1^{\,2}\eta_1^{\,12} \\ &- 24960t_1^{\,4}\eta_1^{\,10} - 23040t_1^{\,4}\eta_1^{\,12} \end{aligned} \right] \right] \tag{61}
$$

Since $\Delta\tau$ is the difference of the true isometric latitudes in order to obtain the geodetic latitude difference from (61) we expand $\Delta\phi$ into a series in $\Delta\tau$ as

$$\Delta\phi = \phi - \phi_1 = \Delta\tau \frac{d\phi_1}{d\tau_1} + \frac{\Delta\tau^2}{2!} \frac{d^2\phi_1}{d\tau_1^2} +$$

$$\cdots\cdots \frac{\Delta\tau^n d^n\phi_1}{n!\, d\tau_1^n} + \cdots\cdots \qquad (62)$$

Now from (46)

$$\frac{d\phi_1}{d\tau_1} = \frac{N_1}{R_1} \cos\phi_1 = (1 + \eta_1^2)\cos\phi_1$$

and by successive differentiation

$$\frac{d^2\phi_1}{d\tau_1^2} = -(1 + \eta_1^2)(1 + 3\eta_1^2)t_1 \cos^2\phi_1$$

$$\frac{d^3\phi_1}{d\tau_1^3} = (1 + \eta_1^2)\Big| 4t_1^2 + 2(1 + \eta_1^2)(1 - 9t_1^2)$$

$$+ 3(1 + \eta_1^2)^2 (5t_1^2 - 1)\Big| \cos^3\phi_1$$

$$\frac{d^4\phi_1}{d\tau_1^4} = -t_1 (1 + \eta_1^2)\Big| -8t_1^2 + 4(1 + \eta_1^2)(21t^2 - 4)$$

$$+ 4(1 + \eta_1^2)^2 (17 - 45t_1^2) + 3(1 + \eta_1^2)^3$$

$$(35\, t_1^2 - 19)\Big| \cos^4\phi_1 \qquad (63)$$

Substituting the value of $\Delta\tau$ from (61) and the values of $\frac{d^n\phi_1}{d\tau_1^n}$ from (63) into (62) and deleting terms in η_1 in the coefficient of $\left(\frac{x}{N_1}\right)^8$ as well as taking note that $1 + \eta_1^2 = \frac{N_1}{R_1}$ we have

$$\phi = \phi_1 - \frac{t_1}{2R_1N_1} x^2 + \frac{t_1}{24R_1N_1^3} x^4 (5 + 3t_1^2 + \eta_1^2$$

$$- 4\eta_1^2 - 9\eta_1^2 t_1^2)$$

$$- \frac{t_1}{720R_1N_1^5} x^6 \left[\begin{array}{l} 61 + 90t_1^2 + 46\eta_1^2 + 45t_1^4 - 252t_1^2\eta_1^2 \\ - 3\eta_1^4 + 100\eta_1^6 - 66t_1^2\eta_1^4 - 90t_1^4\eta_1^2 \\ + 88\eta_1^8 + 225t_1^4\eta_1^4 + 84t_1^2\eta_1^6 - 192t_1^2\eta_1^8 \end{array} \right]$$

$$+ \frac{t_1}{40320R_1N_1^7} x^8 \left(1385 + 3633t_1^2 + 4095\, t_1^4 + 1575t_1^6\right) \tag{64}$$

Equation (60) with the terms containing η_1 in the coefficient of $\left(\frac{x}{N_1}\right)^7$ deleted, along with equation (64) are used to determine the ϕ, λ from the given X, Y location. The $\Delta\lambda$ is added to the value of the central meridian to determine λ. The X and Y values used in the equations have the false Easting and false Northing removed.

3.3 COMPUTER CALCULATION OF UTM FROM LAT-LONG

This routine required double precision floating point arithmetic on a Sigma V computer to maintain sufficient accuracy. An outline of the program is as follows.

a. Input

Semi major axis in meters = a

Central scale factor = k_o (.9996 for UTM)

Inverse flattening factor = 1/f

UTM zone number

Latitude = ϕ radians

Longitude = λ radians

b. Step 1

Calculate

$$a' = k_o \, a$$

$$f = (1/(1/f))$$

$$\epsilon^2 = f\,(2 - f)$$

$$\lambda_o = (-183 + 6\,(\text{zone No}))/57.29....$$

$$\Delta\lambda = \lambda - \lambda_o$$

$$N = a'/(1 - \epsilon^2 \sin^2 \phi)^{1/2}$$

c. Step 2

Calculate S_ϕ from equation (43)

d. Step 3

Calculate x from equation (37)

y from equation (38)

e. Step 4

Add 500,000 meters false Easting to X. Test Y and if negative, subtract Y from 10,000,000 meters false Northing (i.e. add magnitude of Y to 10^6 meters).

3.4 COMPUTER CALCULATION OF LAT-LONG FROM UTM

This routine required double precision floating point arithmetic on a Sigma V computer to maintain sufficient accuracy. An outline of the program is as follows.

a. Input

Semi major axis in meters = a

Central scale factor = k_o (UTM, K_o = .9996)

Inverse flattening factor = 1/f

UTM zone number

X = Easting containing false Easting (meters)

Y = Northing containing false Northing (meters)

b. Step 1

Remove false Easting from X

Test and remove false Northing from Y

λ_o = (-183 + 6 (zone no))/57.29....

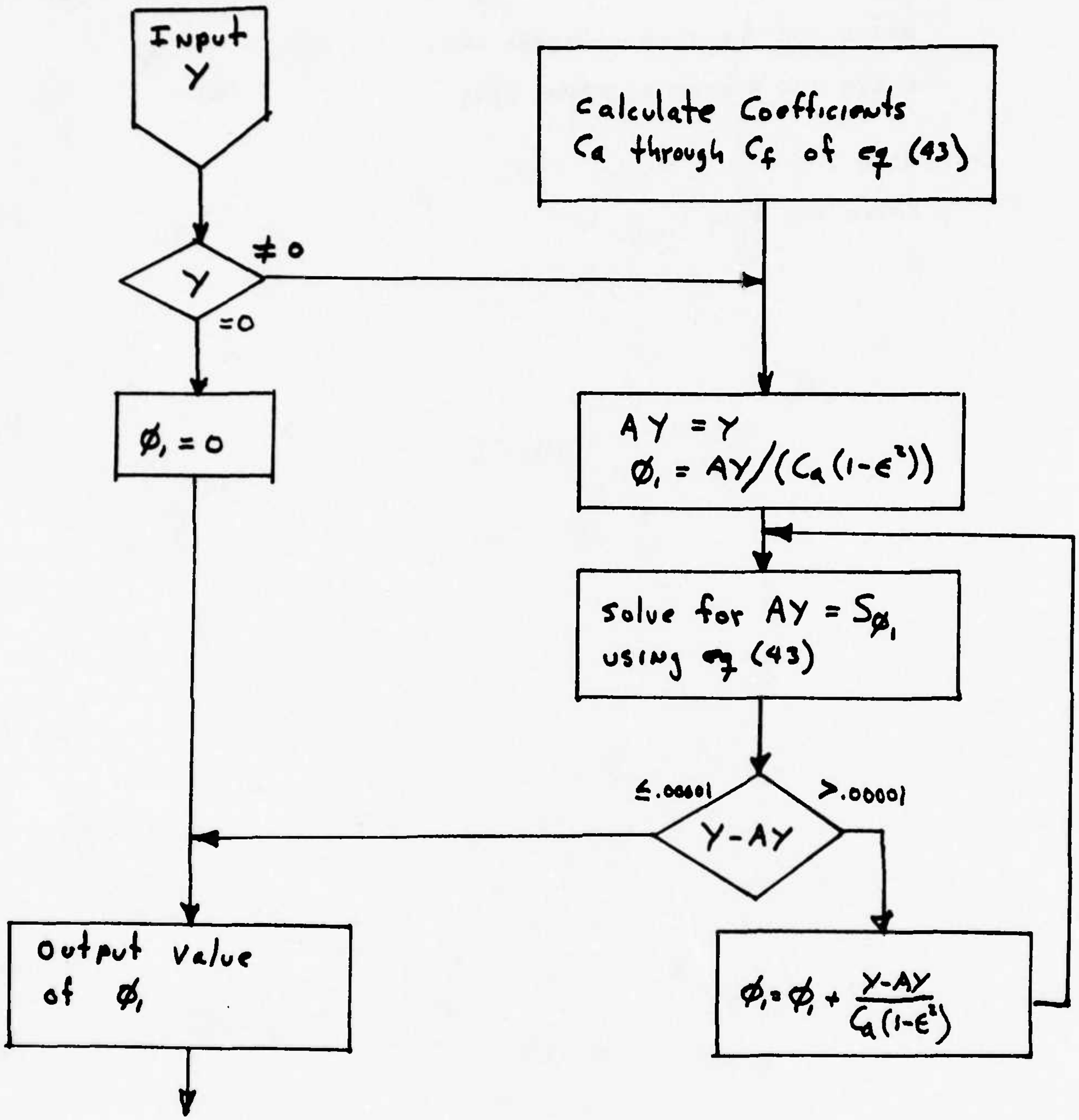
$a' = k_o a$

$\epsilon^2 = f(2 - f)$

c. Step 2

Iteriatively solve for footpoint

Latitude ϕ_1 by the following method


Input Y
Y
≠0
=0
Calculate Coefficients C_a through C_f of eq (43)
$\phi_1 = 0$
AY = Y
$\phi_1 = AY/(C_a(1-\epsilon^2))$
solve for $AY = S_{\phi_1}$ using eq (43)
≤.00001
>.00001
Y-AY
Output Value of ϕ_1
$\phi_1 = \phi_1 + \frac{Y-AY}{C_a(1-\epsilon^2)}$

d. Step 3

Solve for $\Delta \lambda$ from equation (60)

Solve for ϕ from equation (64)

e. Step 4

Solve for λ as $\lambda_o + \Delta$

4.0 LOCAL COORDINATE CONVERSION

4.1 LAT-LONG TO LOCAL COORDINATES

The local coordinate system chosen for data reduction is a cartesian X, Y, Z coordinate system with the Y axis oriented north at the origin, X oriented to the east at the origin and Z vertical. The X-Y plane is normal to the spheroid at the reference or origin point.

Setting up a geocentric coordinate system with the $X_1 - X_2$ plane in the equatorial plane and X_3 oriented north as shown in Figure 5, the coordinate system X'_k as shown in Figure 6 is related to X_k as follows:

$$x_1 = x_1' \cos \lambda - x_2' \sin \lambda$$

$$x_2 = x_1' \sin \lambda - x_2' \cos \lambda \qquad (65)$$

$$x_3 = x_3'$$

and

$$x_1' = E \cos \phi_g + h \cos \phi$$

$$x_2' = 0 \qquad (66)$$

$$x_3' = E \sin \phi_g + h \sin \phi$$

where λ is the longitude angle, ϕ is the geodetic latitude, ϕ_g is the geocentric latitude and h is the geodetic elevation of point M.

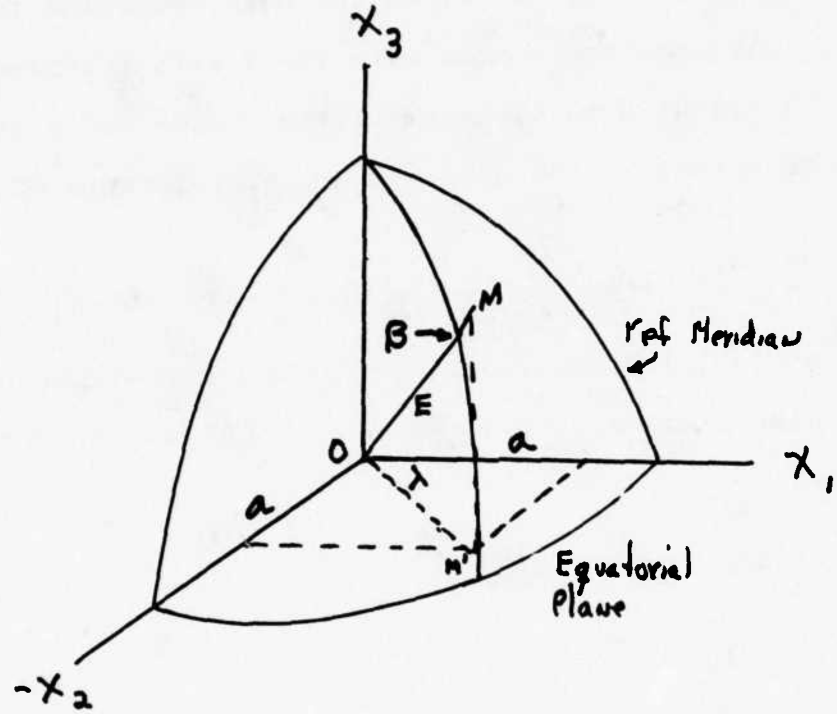


Figure 5. Geocentric Coordinate System

Equation (65) also may be written as

$$x_1 = \cos\lambda\,(E\cos\phi_g + h\cos\phi)$$

$$x_2 = \sin\lambda\,(E\cos\phi_g + h\cos\phi) \tag{67}$$

$$x_3 = E\sin\phi_g + h\sin\phi$$

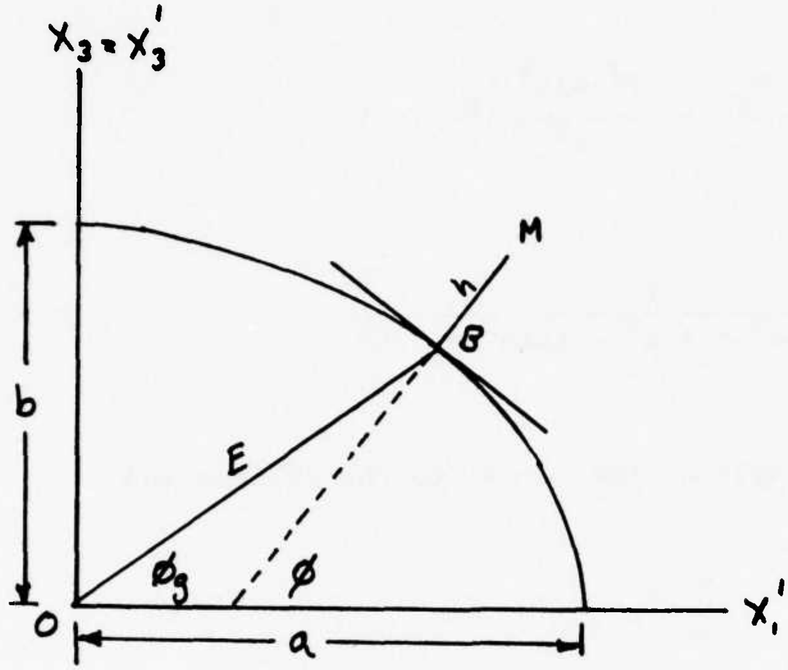


Figure 6. Rotated $x_k{}'$ Coordinate System

Now on the surface of the spheroid, the intersection of the $x_1{}'$ $x_3{}'$ plane with the spheroid is an ellipse expressed by

$$\frac{x_1{}'^2}{a^2} + \frac{x'_3{}^2}{b^2} = 1$$

$$\begin{aligned} x_1{}' &= E \cos \phi_g \\ x_3{}' &= E \sin \phi_g \end{aligned} \qquad (68)$$

So that

$$E^2 \frac{\cos^2 \phi_g}{a^2} + \frac{E^2 \sin^2 \phi_g}{b^2} = 1 \qquad (69)$$

or

$$E^2 = \frac{1}{(\cos^2 \phi_g)/a^2 + (\sin^2 \phi_g)/b^2} \qquad (70)$$

Since ϕ is the angle of the normal to the ellipse and

$$\tan \phi = - \frac{dx'_1}{dx'_3} \qquad (71)$$

differentiating (68) with respect to $x_3{}'$

$$\frac{x_1{}'}{a^2} \frac{dx'_1}{dx'_3} + \frac{x'_3}{b^2} = 0 \qquad (72)$$

So that

$$\tan \phi = \frac{a^2}{b^2} \frac{x'_3}{x'_1} = \frac{a^2}{b^2} \tan \phi_g \qquad (73)$$

Since $\epsilon^2 = (a^2 - b^2)/a^2$

$$\tan \phi_g = (1 - \epsilon^2) \tan \phi \qquad (74)$$

and

$$E^2 = \frac{b^2}{1 - \epsilon^2 \cos^2 \phi_g} \qquad (75)$$

4.1 LOCAL COORDINATE SYSTEM

Let x_1'', x_2'' and x_3'' be a coordinate system with its origin at reference position A as shown in Figure 7.

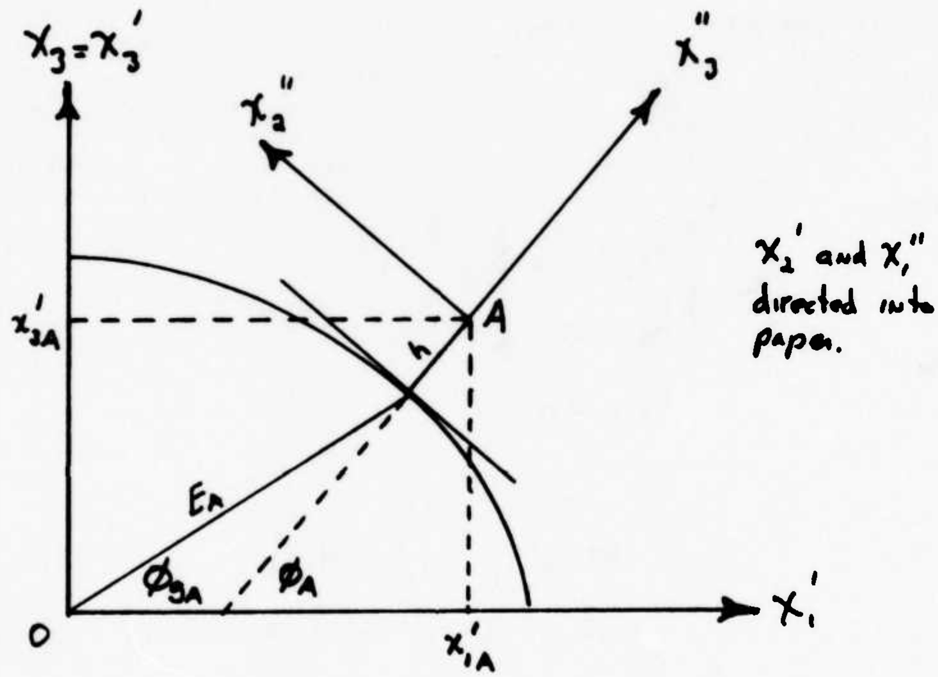


Figure 7. Local Coordinate System with Origin at A

Then

$$\begin{bmatrix} x_1'' \\ x_2'' \\ x_3'' \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ -\sin\phi_A & 0 & \cos\phi_A \\ \cos\phi_A & 0 & \sin\phi_A \end{bmatrix} \begin{bmatrix} x_1' - x_1'{}_A \\ x_2' \\ x_3' - x_3'{}_A \end{bmatrix} \tag{80}$$

and

$$\begin{bmatrix} x_1' - x_{1\,A}' \\ x_2' \\ x_3' - x_{3\,A}' \end{bmatrix} = \begin{bmatrix} \cos\lambda_A & \sin\lambda_A & 0 \\ -\sin\lambda_A & \cos\lambda_A & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 - x_{1A} \\ x_2 - x_{2A} \\ x_3 - x_{3A} \end{bmatrix} \tag{81}$$

Substituting back into (80)

$$x'' = AD \tag{82}$$

where

$$D = \begin{bmatrix} x_1 - x_{1A} \\ x_2 - x_{2A} \\ x_3 - x_{3A} \end{bmatrix} \tag{83}$$

and

$$A = \begin{bmatrix} -\sin\lambda_A & \cos\lambda_A & 0 \\ -\cos\lambda_A \sin\phi_A & -\sin\phi_A \sin\lambda_A & \cos\phi_A \\ \cos\phi_A \cos\lambda_A & \cos\phi_A \sin\lambda_A & \sin\phi_A \end{bmatrix} \tag{84}$$

The local coordinates can then be determined by use of equation set (67) to solve for X and X_A utilizing (74) and (75) to determine ϕ_g, ϕ_{gA}, E and E_A.

4.2 LOCAL COORDINATES TO LAT-LONG

The inverse solution is not as straight forward as the LAT-LONG to LC in that the set of equations (67), (74), and (75) relating X to LAT-LONG-h are not linear. To solve this set, some sort of iterative approach is necessary. One method would be to rearrange (82) as

$$x = A^{-1} x'' + x_A \tag{85}$$

and then iteratively solve for LAT-LONG from x. This, however, introduces some error in the calculation in that errors in the inversion of A are propagated to the answer. A better approach is to estimate the geographic coordinates and solve for the LOCAL coordinates in a manner to minimize the square error between the input local coordinates and the computed local coordinates derived from an estimate of the geographic coordinates. Figure 8 gives a block diagram of the solution where

Geographic coordinates are

$$W_1 = \phi, \; W_2 = \lambda, \; W_3 = h \tag{86}$$

Local X Y Z are

$$x_1'' = x, \; x_2'' = y, \; x_3'' = z \tag{87}$$

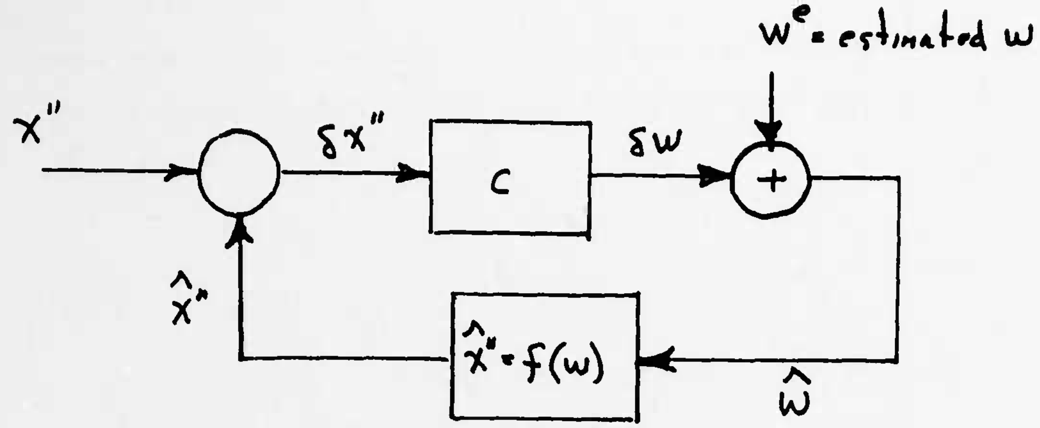


Figure 8. Inverse Solution Block Diagram

In this solution, the block relating x" as a function of W is the LAT-LONG to local coordinate conversion routine outlined in 4.1. Matrix C relates the geographic error vector to the local coordinate error vector in a manner to minimize the square of the error between x" and $\hat{x}''$. The vector equations are

$$B^T B \ \delta_W = B^T \ \delta_x{}'' \tag{88}$$

or

$$\delta_W = (B^T B)^{-1} \ B^T \ \delta_x{}'' = C \ \ \delta_x{}''$$

where

$$B^T = -\begin{bmatrix} \frac{\partial x_1''}{\partial W_1} & \frac{\partial x_2''}{\partial W_1} & \frac{\partial x_3''}{\partial W_1} \\ \frac{\partial x_1''}{\partial W_2} & \frac{\partial x_2''}{\partial W_2} & \frac{\partial x_3''}{\partial W_2} \\ \frac{\partial x_1''}{\partial W_3} & \frac{\partial x_2''}{\partial W_3} & \frac{\partial x_3''}{\partial W_3} \end{bmatrix} \tag{89}$$

From (82) and (83)

$$x'' = Ax - Ax_A \tag{90}$$

So that

$$B = -AF \tag{91}$$

where A is defined in (84) and

$$F = \begin{bmatrix} \frac{\partial x_1}{\partial W_1} & \frac{\partial x_1}{\partial W_2} & \frac{\partial x_1}{\partial W_3} \\ \frac{\partial x_2}{\partial W_1} & \frac{\partial x_2}{\partial W_2} & \frac{\partial x_2}{\partial W_3} \\ \frac{\partial x_3}{\partial W_1} & \frac{\partial x_3}{\partial W_2} & \frac{\partial x_3}{\partial W_3} \end{bmatrix} \tag{92}$$

Since

$$\phi_g \approx \phi \tag{93}$$

we may approximate (67) as

$$
\begin{aligned}
x_1 &\approx (E + h) \cos \phi \cos \lambda = (E + W_3) \cos (W_1) \cos (W_2) \\
x_2 &\approx (E + h) \cos \phi \sin \lambda = (E + W_3) \cos (W_1) \sin (W_2) \\
x_3 &\approx (E + h) \sin \phi = (E + W_3) \sin (W_1)
\end{aligned}
\tag{94}
$$

Then

$$\frac{\partial x_1}{\partial W_1} = - (E + W_3) \cos (W_2) \sin (W_1)$$

$$\frac{\partial x_2}{\partial W_1} = - (E + W_3) \sin (W_2) \sin (W_1)$$

$$\frac{\partial x_3}{\partial W_1} = (E + W_3) \cos (W_1)$$

$$\frac{\partial x_1}{\partial W_2} = - (E + W_3) \cos (W_1) \sin (W_2)$$

$$\frac{\partial x_2}{\partial W_2} = (E + W_3) \cos (W_1) \cos (W_2)$$

$$\frac{\partial x_3}{\partial W_2} = 0$$

$$\frac{\partial x_1}{\partial W_3} = \cos(W_2)\cos(W_1)$$

$$\frac{\partial x_2}{\partial W_3} = \sin(W_2)\cos(W_1)$$

$$\frac{\partial x_3}{\partial W_3} = \sin(W_1) \tag{95}$$

4.3 COMPUTER CALCULATION OF LOCAL COORDINATES FROM GEOGRAPHIC COORDINATES

The computer program utilizes equation sets (67), (74), (75), (82), (83) and (84) to determine the local cartesian coordinates. Although some problems can occur in solving for points close to the coordinate origin where the major positional difference is altitude, utilization of double precision arithmetic on the Sigma V computer appeared to be quite adequate for this method of solution. This avoided the problem of requiring different routines for different regions.

The method of solution is as follows:

Step 1

Input

- a = Semi major axis in meters
- $1/f$ = Inverse flattening factor
- R_i = Reference Lat-Long in radians, altitude in meters
- W_i = Geographic coordinates of point to be converted in LAT, LONG in radians, altitude in meters

Step 2

Calculate

$$f = 1/(1/f)$$

$$\epsilon^2 = f(2 - f)$$

$$b = a(1 - f)$$

$$E_A = b/(1 - \epsilon^2 \cos^2 \phi_A)$$

$$\phi_{g_A} = \tan^{-1} ((1 - \epsilon^2) \tan \phi_A)$$

Set up A array equation (84).

Calculate

x_A as RX_i from equation (67)

Step 3

Calculate

$$E = b/(1 - \epsilon^2 \cos^2 \phi)$$

$$\phi_g = \tan^{-1}((1 - \epsilon^2) \tan \phi)$$

x as PX_i from equation (67)

Step 4

$$x'' = A(x - x_A)$$

4.4 COMPUTER CALCULATION OF GEOGRAPHIC COORDINATES FROM LOCAL COORDINATES

The program follows the method outlined in 4.1 utilizing the conversion method of 4.3 to convert estimated geographic coordinates to local coordinates. Double precision on the Sigma V is utilized in the arithmetic and appeared to be more than adequate in the solution. A test of all programs was run utilizing the UTM-GEOGRAPHIC routines as well as the LC-GEOGRAPHIC. This test involved setting a reference on a reference meridian and offsetting the point in UTM grid by increments of 10 meters in Northing and Easting and varying altitude from 0 to 500 meters in steps of 100 meters. The UTM points were converted to Geographic to LOCAL to GEOGRAPHIC to UTM with an error of less than .0001 meters altitude, .001 meters in X and Y and 1.0×10^{-8} radians.

The inverse solution method is as follows.

Step 1

Input

a = semi major axis in meters

$1/f$ = inverse flattening factor

R_i = reference geographic coordinates in ϕ, λ, h

x'' = local cartesian coordinate value of the point.

Step 2

Calculate

$$f = 1/(1/f)$$

$$\epsilon^2 = f(2 - f)$$

$$b = a(1 - f)$$

$$E_A = b/(1 - \epsilon^2 \cos^2 \phi_A)$$

$$\phi g_A = \tan^{-1} ((1 - \epsilon^2) \tan \phi_A)$$

Set up A array equation (84).

Calculate

X_A as RX_i from equation (67).

Step 3

Choose initial $W^e = R$.

Step 4

Iteration procedure as in Figure 8

Calculate

$$E = b/(1 - \epsilon^2 \cos^2 \phi)$$

$$\phi_g = \tan^{-1} ((1 - \epsilon^2) \tan \phi$$

x as PX from equation (67)

Step 5

$$\hat{x}'' = A (x - x_A)$$

$$\Delta x'' = x'' - \hat{x}''$$

Test Δx

If $\Delta x < .01$ stop iteration.

Step 6

Set up F array as in (92).

Calculate B and B^T as in (91).

Calculate $(B^TB)^{-1} B^T = A$

Calculate new W^e as $W^e - A \Delta x''$

Return to Step 4.

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4. Jorden-Eggert, "Handbook of Geodesy", Volume III, First Half, Washington, Army Map Service Translation, 1962.
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MAIN LINE TEST PROGRAM

```
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION SECLT(20),SECLN(20),RLAT(20),RLON(20)
      DOUBLE PRECISION LCE,LCN
      DIMENSION ISNLT(20),IDLT(20),IMLT(20),ISNLN(20),IDLN(20),IMLN(20)
      DIMENSION A(10),F(10),ITITLE(10,80),SCALE(3)
      DIMENSION IZ(20),EAST(20),NORTH(20)
      DIMENSION I_Z(20),LCE(20),LCN(20),R(3),W(3),XX(3),ELEV(20),ALC(20,
     *3)
      DOUBLE PRECISION NORTH
      DATA CON/57.2957795130823 21/
      Z=123456.
 1000 FORMAT(1H1)
 1001 FORMAT(1H0)
 1002 FORMAT(5F20.0)
 1003 FORMAT(80A1)
      DO 10 I=1,10
 10   READ 1003,(ITITLE(I,J),J=1,80)
      DO 11 I=1,10
 11   READ 1002,A(I),F(I)
      DO 12 I=1,3
 12   READ 1002,SCALE(I)
      READ 1004,N
      DO 15 I=1,N
 15   READ 1005,ISNLT(I),IDLT(I),IMLT(I),SECLT(I),ISNLN(I),IDLN(I),
     *IMLN(I),SECLN(I)
      DO 20 I=1,N
      RLAT(I)=RAFA(ISNLT(I),IDLT(I),IMLT(I),SECLT(I))
 20   RLON(I)=RAFA(ISNLN(I),IDLN(I),IMLN(I),SECLN(I))
 1004 FORMAT(5I20)
 1005 FORMAT(1A1,2I4,F10.0,1A1,2I4,F10.0)
      K=1;J=0
      I=5
      PRINT 1000
      PRINT 1003,(ITITLE(I,M),M=1,80)
      PRINT 1006,SCALE(K)
      PRINT 1001
      PRINT 1008
 1006 FORMAT($ CENTRAL SCALE FACTOR = $F8.4)
      DO 40 II=1,N
      IZONE = NZUTM(RLON(II))+J
      IF(IZONE.EQ.0)IZONE=60
      IF(IZONE.EQ.61)IZONE=1
      CALL XYFLL(IZONE,X,Y,SCALE(K),A(I),F(I),RLAT(II),RLON(II))
```

```
      PRINT 1007,ISNLT(II),IDLT(II),IMLT(II),SECLT(II),ISNLN(II),
     *IDLN(II),IMLN(II),SECLN(II),IZONE,X,Y
      IF(I.EQ.5)IZ(II)=IZONE;EAST(II)=X;NORTH(II)=Y
40    CONTINUE
100   CONTINUE
      READ 1004,M
      REPEAT 200, FOR I=(1,M)
      READ 1017,IZ(I),EAST(I),NORTH(I)
200   CONTINUE
1018  FORMAT(7X,I3,5X,2F18.4,5X,2(1A1,2I3,F8.4,2X))
1019  FORMAT(4X,$UTM ZONE$12X$EASTING$11X$NORTHING$9X$LATITUDE$9X$LONGIT
     *UDE$/25X$METERS$12X$METERS$9X$D$3X$M$3X$SEC$7X$D$2X$M$3X$SEC$/)
      IF(M.EQ.0)STOP
      I=5
      PRINT 1000
      PRINT 1003,(ITITLE(I,MM),MM=1,80)
      PRINT 1006,SCALE(K)
      PRINT 1001
      PRINT 1019
      DO 240 II=1,M
      CALL LLFXY(IZ(II),EAST(II),NORTH(II),SCALE(K),A(I),F(I),ALA,ALO)
      CALL DEGRE(ALA,IST,IDT,IMT,ST)
      CALL DEGRE(ALO,ISL,IDL,IML,SL)
      IDT=IABS(IDT),IDL=IABS(IDL)
      PRINT 1018,IZ(II),EAST(II),NORTH(II),IST,IDT,IMT,ST,ISL,IDL,IML,SL
240   CONTINUE
210   CONTINUE
1017  FORMAT(I3,3F20.0)
      READ 1004,L
      IF(L.EQ.0) STOP
      READ 1017,IZREF,REFE,REFN
      REPEAT 400,FOR I=(1,L)
      READ 1017,I_Z(I),LCE(I),LCN(I),ELEV(I)
400   CONTINUE
       R(3)=0.
      I=5
      CALL LLFXY(IZREF,REFE,REFN,SCALE(K),A(I),F(I),R(1),R(2))
      CALL DEGRE(R(1),IIST,IIDT,IIMT,SST)
      CALL DEGRE(R(2),IISL,IIDL,IIML,SSL)
      IIDT=IABS(IIDT);IIDL=IABS(IIDL)
      PRINT 1000
      PRINT 1003,(ITITLE(I,MM),MM=1,80)
      PRINT 1006,SCALE(K)
      PRINT 1001
```

```
      PRINT 1020
1020  FORMAT($ LOCAL REFERENCE$)
      PRINT 1001
      PRINT 1019
      PRINT 1018,IZREF,REFE,REFN,IIST,IIDT,IIMT,SST,IISL,IIDL,IIML,SSL
      PRINT 1001
      PRINT 1021
1021  FORMAT(X$UTM ZONE$3X$EASTING$7X$NORTHING$5X$ELEVATION$10X$X$12X$Y$
     *12X$Z$/13X$METERS$9X$METERS$6X$METERS$10X$METERS$8X$METERS$6X$METE
     *RS$/)
1022  FORMAT(4X,I2,2F15.4,F12.4,F16.4,F14.4,F12.4)
      DO 401 II=1,L
      CALL LLFXY(ILZ(II),LCE(II),LCN(II),SCALE(K),A(I),F(I),W(1),W(2))
      W(3)=ELEV(II)
      IF(II.GT.1)GO TO 405
      CALL LLTLC(R,W,XX,A(I),F(I))
      GO TO 406
405   CALL GEOTLC(W,XX)
406   CONTINUE
      PRINT 1022,ILZ(II),LCE(II),LCN(II),W(3),XX(1),XX(2),XX(3)
      IF(I.EQ.5)XLC(II,1)=XX(1);XLC(II,2)=XX(2);XLC(II,3)=XX(3)
401   CONTINUE
      I=5
      CALL LLFXY(IZREF,REFE,REFN,SCALE(K),A(I),F(I),R(1),R(2))
      CALL DEGRE(R(1),IIST,IIDT,IIMT,SST)
      CALL DEGRE(R(2),IISL,IIDL,IIML,SSL)
      IIDT=IABS(IIDT);IIDL=IABS(IIDL)
      PRINT 1000
      PRINT 1003,(ITITLE(I,MM),MM=1,80)
      PRINT 1005,SCALE(K)
      PRINT 1001
      PRINT 1020
      PRINT 1001
      PRINT 1019
      PRINT 1018,IZREF,REFE,REFN,IIST,IIDT,IIMT,SST,IISL,IIDL,IIML,SSL
      PRINT 1001
      PRINT 1023
1023  FORMAT(7X$X$13X$Y$11X$Z$9X$UTM ZONE$3X$EASTING$7X$NORTHING$5X$ELEV
     *ATION$/5X$METERS$8X$METERS$6X$METERS$18X$METERS$9X$METERS$6X$METER
     *S$/)
1024  FORMAT(XF12.4,F14.4,F12.4,7X,I2,2F15.4,F12.4)
      DO 501 II=1,L
      DO 502 III=1,3
502   XX(III)=XLC(II,III)
```

```
      IF(II.GT.1)GO TO 503
      CALL LCTLL(R,W,XX,A(I),F(I))
      GO TO 504
503   CALL LCTGEO(W,XX)
504   CONTINUE
      IZONE=NZUTM(W(2))
      CALL XYFLL(IZONE,X,Y,SCALE(K),A(I),F(I),W(1),W(2))
      PRINT 1024, XX(1),XX(2),XX(3),IZONE,X,Y,W(3)
501   CONTINUE
      STOP
1007  FORMAT(X,2(1A1,2I3,F8.4,2X),5X,I3,5X,2F18.4)
1008  FORMAT(4X,$_ATITUDE$,9X,$LONGITUDE$,27X,$EASTING$,11X,$NORTHING$
     */3X$D$3X$M$3X$SEC$6X$D$3X$M$3X$SEC$6X$UTM ZONE$13X$METERS$12X$METE
     *RS$/)
      END
```

```
      SUBROUTINE XYFLL(NOZ,X,Y,KO,EA,EFI,FLA,FLO)
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      DOUBLE PRECISION K,N,KO
C
C     SUBROUTINE CONVERTS LATITUDE AND LONGITUDE INTO UTM COORDINATES
C     FLA=LATITUDE IN RADIANS
C     FLO = LONGITUDE IN RADIANS
C     EA=SEMI MAJOR AXIS
C     EFI=INVERSE FLATTENING
C     NOZ=NUMBER OF ZONE
C     LOZ=LONG OF CENTRAL MERIDIAN
C     KO=CENTRAL SCALE FACTOR
C     X,Y = PLANE CO-ORDINATES
C
      DATA RHOD/57.295779513082321/
      LOZ=-183+6*NOZ
      A=EA*KO
      F=1./EFI
      E=F*(2-F)
      FLZ=LOZ/RHOD
      DL=FLO-FLZ
      IF(DL.LT.-5.2)DL=DL+360./RHOD
      IF(DL.GT.5.2)DL=DL-360./RHOD
      SNFLA=DSIN(FLA)
      CNFLA=DCOS(FLA)
      SNFLA2=SNFLA*SNFLA
      CNFLA2=CNFLA*CNFLA
      N=A/DSQRT(1.-E*SNFLA2)
      E2=E*E
      E4=E2*E2
      CA=1.+.75*E+45.*E2/64.+175.*E*E2/256.+11025.*E4/16384.
      CB=.75*E+E2*15./16.+E*E2*525./512.+E4*2205./2048.
      CC=E2*15./64.+E*E2*105./256.+E4*2205./4096.
      CD=E*E2*35./512.+E4*315./2048.
      CE=E4*315./16384.
      S=A*(1.-E)*(CA*FLA-CB/2.*DSIN(2*FLA)+CC/4.*SIN(4*FLA)-CD/6*SIN(6.*
     *FLA)+CE/8.*SIN(8.*FLA))
      TSQ=SNFLA2/CNFLA2
      TSQ2=TSQ*TSQ
      ETAS=E/(1.-E)*CNFLA2
      ETA4=ETAS*ETAS
      DL2=DL*DL
      DL4=DL2*DL2
```

```
      DLXCN=DL*CNFLA
      XP1=N*DL*CNFLA+N*(DLXCN)**3/6.*(1.-TSQ+ETAS)
      XP11=N*(DLXCN)**5/120.
      XP12=5.-18.*TSQ+TSQ**2+14.*ETAS-58.*TSQ*ETAS
      XP13=13.*ETAS**2+4.* ETAS**3-64.*ETAS**2*TSQ-24.*ETAS**3*TSQ
      XP2=XP11*(XP12+XP13)
      XP3=N*DL**7*(COS(FLA))**7/5040.*(61.-479.*TSQ+179.*TSQ**2-TSQ**3)
      XT=(XP1+XP2+XP3)
      YP1=S+N/2.*DL2*SNFLA*CNFLA+N*DL4/24.*SNFLA*(CNFLA)**3*(5.-TSQ+9.*
     * ETAS+4.*ETA4)
      YP11=N*DL4*DL2/720.*SNFLA*(CNFLA)**5
      YP12=61.-58.*TSQ+TSQ**2+270.*ETAS-330.*TSQ*ETAS
      YP13=445.*ETA4+324.*ETA4*ETAS-680.*ETA4*TSQ
      YP14=88.*ETA4*ETA4-600.*ETA4*ETAS*TSQ-192.*ETA4*ETA4*TSQ
      YP2=YP11*(YP12+YP13+YP14)
      YP3=N*DL4*DL4/40320.*SNFLA*(CNFLA)**7*(1385.-3111.*TSQ+543.*TSQ2-
     *TSQ2*TSQ)
      YT=(YP1+YP2+YP3)
      X=500000.+XT
      Y=YT
      IF(YT.LT.0)Y=10000000.-YT
      RETURN
      END
```

```
      SUBROUTINE ULFXY(NZONE,XT,YT,CSF,A ,F,RLAT,RLONG)
C
C     SUBROUTINE CONVERTS UTM X,Y COORDINATES INTO LAT. AND LONG. IN RAD
C     NZONE = UTM ZONE
C     CSF = CENTRAL SCALE FACTOR
C     A   = SEMI MAJOR AXIS
C     F= INVERSE FLATTENING
C     RLAT = LATITUDE IN RADIANS
C     RLONG = LONGITUDE IN RADIANS
C
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      DOUBLE PRECISION N1,LAMDIF,LAMCM,LAM
C
      INTEGER GAMD,GAMM
      DATA CON/57.2957795130823217
      X=XT-500000.
      Y=YT
      IF(Y.GE.10000000.)Y=10000000.-YT
      LCM=-183+6*NZONE
      LAMCM=LCM/CON
      AE=CSF*A
      ES=2./F-1./(F*F)
      E4=ES*ES
      E6=E4*ES
      E8=E4*E4
      E10=E6*E4
      AC=1.+.75*ES+E4*45./64.+E6*175./256.+E8*11025./16384.+E10*
     *  43659./65536.
      BC=(.75*ES+E4*15./16.+E6*525./512.+E8*2205./2048.+E10*
     *  72765./65536.)/2.
      CC=(E4*15./64.+E6*105./256.+E8*2205./4096.+E10*10395./16384.)/4.
      DC=(E6*35./512.+E8*315./2048.+E10*31185./131072.)/6.
      EC=(E8*315./16384.+E10*3465./65536.)/8.
      FC=(E10*693./131072.)/10.
      FAC=AE*(1.-ES)
      IF(Y.NE.0)GO TO 102
      FEE1=0.
      GO TO 103
  102 AY=Y
      FEE1=AY/(FAC*AC)
  104 AY=FAC*(AC*FEE1-BC*DSIN(2.*FEE1)+CC*DSIN(4.*FEE1)-DC*DSIN(6.*FEE1)
     * +EC*DSIN(8.*FEE1)-FC*DSIN(10.*FEE1))
      YDIF=Y-AY
```

```
      IF(DABS(YDIF).LT..00001)GO TO 103
      AAY=YDIF/(FAC*AL)
      FEE1=FEE1+AAY
      GO TO 104
 103  FEESIN=DSIN(FEE1)
      FEECOS=DCOS(FEE1)
      W=DSQRT(1.-ES*FEESIN*FEESIN)
      N1=AE/W
      R1=N1*(1.-ES)/(W*W)
      T=FEESIN/FEECOS
      T2=T*T
      T4=T2*T2
      T6=T4*T2
      ETA2=(ES/(1.-ES))*DCOS(FEE1)*DCOS(FEE1)
      ETA4=ETA2*ETA2
      ETA6=ETA4*ETA2
      ETA8=ETA4*ETA4
      T2E2=T2*ETA2
      T2E4=T2*ETA4
      T4E2=T4*ETA2
      T4E4=T4*ETA4
      T2E6=T2*ETA6
      T2E8=T2*ETA8
      IF(X.EQ.0.)GO TO 105
      XN=X/N1
      XN3=XN*XN*XN
      XN2=XN*XN
      XN4=XN2*XN2
      XN6=XN3*XN3
      XN5=XN3*XN2
      XN7=XN3*XN4
      IF(Y.EQ.0.)GO TO 106
      FT1=-X*X/(2.*R1*N1)+(XN3*(X/(24.*R1)))*(5.+3.*T2+ETA2-4.*ETA4-9.*
     * T2E2)
      FPT1=(61.+90.*T2+46.*ETA2+45.*T4-252.*T2E2-3.*ETA4)
      FPT2=(100.*ETA6-66.*T2E4-90.*T4E2+88.*ETA8+225.*T4E4+84.*T2E6-
     * 192.*T2E8)
      FT2=(XN5*(X/(720.*R1)))*(FPT1+FPT2)
      FPT3=1385.+3633.*T2+4095.*T4+1575.*T6
      FT3=(XN7*(X/(40320.*R1)))*FPT3
      FEEDIF=T*(FT1-FT2+FT3)
 106  IF(Y.EQ.0.)FEEDIF=0.
      TL1=XN-(XN3/6.*(1.+2.*T2+ETA2))
      TLP1=(5.+6.*ETA2+28.*T2-3.*ETA4+8.*T2E2)
```

```
      TLP2=(24.*T4-4.*ETA6+4.*T2E4+24.*T2E6)
      TL2=(XN5/120.)*(TLP1+TLP2)
      TLP3=(61.+662.*T2+1320.*T4+720.*T6)
      TL3=(XN7/5040.)*TLP3
      LAMDIF=(TL1+TL2-TL3)/FEECOS
      IF(X.NE.0.)GO TO 107
105   LAMDIF=0.
      FEEDIF=0.
107   FEE=FEE1+FEEDIF
      LAM=LAMCM+LAMDIF
      RLAT=FEE
      RLONG=LAM
      RETURN
      END
```

```
      SUBROUTINE LCTLL(R,W,X,AE,EFI)
C
C     CONVERTS LOCAL X,Y,Z COORDINATES TO GEOGRAPHIC
C     R(1),R(2),R(3) = LAT,LONG, ELEV OF LOCAL REF IN RADIANS AND METERS
C     W(1) = LAT, LONG, ELEV OF CONVERTED POINT
C     X(1),X(2),X(3) = EAST, NORTH, VERT FROM REFERENCE IN METERS
C     AE=SEMIMAJOR AXIS IN METERS
C     EFI=1/F INVERSE FLATTENING
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION A(3,3),BI(5,5),BT(3,3),B(3,3),R(3),W(3),X(3),T(3,3)
      DIMENSION RX(3),PX(3),XE(3),DX(3)
      F=1./EFI
      EE=F*(2.-F)
      BB=AE*(1.-F)
      COSLATR=DCOS(R(1))
      RADR=BB/DSQRT(1.-EE*COSLATR*COSLATR)
      PHIRG=DATAN((1.-EE)*DTAN(R(1)))
X      OUTPUT F,EE,BB,COSLATR,RADR,PHIRG
C
      A(1,1)=-DSIN(R(2))
      A(1,2)=DCOS(R(2))
      A(3,3)=DSIN(R(1))
      A(2,3)=DCOS(R(1))
      A(3,1)=A(2,3)*A(1,2)
      A(3,2)=-A(2,3)*A(1,1)
      A(2,1)=-A(1,2)*A(3,3)
      A(2,2)=A(3,3)*A(1,1)
      A(1,3)=0.
X     OUTPUT A
C
      RX(1)=A(1,2)*(RADR*DCOS(PHIRG)+R(3)*DCOS(R(1)))
      RX(2)=-A(1,1)*(RADR*DCOS(PHIRG)+R(3)*DCOS(R(1)))
      RX(3)=RADR*DSIN(PHIRG)+R(3)*DSIN(R(1))
X     OUTPUT RX
C
      ENTRY LCTGEO(W,X)
C
C     LCTGEO ENTRY USED FOR MULTIPLE CONVERSIONS OF POINTS USING SAME
C     REFERENCE.  BEFORE USING LCTGEO, AN INITIAL CALL OF LCTLL MUST
C     BE MADE TO INITIALIZE SUBROUTINE TO LOCAL REFERENCE.
C
C
```

```
C      SET INITIAL CONDITIONS
C
       IN=0
       DO 10 I=1,3
10     W(I)=R(I)
X      OUTPUT W
C
C      START ITERATION
C
500    IN=IN+1
       COSLATP=DCOS(W(1))
       RADP=BB/DSQRT(1.-EE*COSLATP*COSLATP)
       PHIPG=DATAN((1.-EE)*DTAN(W(1)))
X      OUTPUT COSLATP,RADP,PHIPG
       PX(1)=DCOS(W(2))*(RADP*DCOS(PHIPG)+W(3)*DCOS(W(1)))
       PX(2)=DSIN(W(2))*(RADP*DCOS(PHIPG)+W(3)*DCOS(W(1)))
       PX(3)=RADP*DSIN(PHIPG)+W(3)*DSIN(W(1))
X      OUTPUT PX
C
       DO 20 I=1,3
       XE(I)=0.
       DO 20 J=1,3
20     XE(I)=XE(I)+A(I,J)*(PX(J)-RX(J))
X      OUTPUT XE
C
C      TEST FOR CONVERGENCE
C
       DO 30 I=1,3
       IF(DABS(X(I)-XE(I)).GT..01)GO TO 50
30     CONTINUE
       RETURN
50     CONTINUE
       DO 40 I=1,3
40     DX(I)=X(I)-XE(I)
X      OUTPUT DX
       EH=RADP+W(3)
       CL=DCOS(W(2))
       SL=DSIN(W(2))
        CT=DCOS(W(1))
       ST=DSIN(W(1))
        T(2,1)=        EH*SL*ST
        T(3,1)        =-EH*CT
        T(1,2)        =EH*CT*SL
        T(3,2)        =0.
```

```
          T(1,3)       =-CL*CT
          T(2,3)       =-SL*CT
          T(3,3)       =-ST
          T(1,1)       =EH*CL*ST
          T(2,2)       =-EH*CT*CL
         DO 60 K=1,3
         DO 60 J=1,3
         SUM=0.
         DO 61 I=1,3
61       SUM=SUM+ A(K,I)*T(I,J)
60       B(K,J)=BT(J,K)=SUM
X        OUTPUT EH,SL,CL,ST,CT,BI,B,T
         DO 90 K=1,3
         DO 90 J=1,3
         SUM=0.
         DO 91 I=1,3
91       SUM=SUM+BT(K,I)*B(I,J)
90       BI(K,J)=SUM
X        OUTPUT BI
         N=3
         NR=5
         CALL DMATINV(BI,N,NR)
X        OUTPUT BI
         DO 70 K=1,3
         DO 70 J=1,3
         SUM=0.
         DO 71 I=1,3
71       SUM=SUM+BI(K,I)*BT(I,J)
70       B(K,J)=SUM
X        OUTPUT B
C
         DO 80 I=1,3
         SUM=0.
         DO 81 J=1,3
81       SUM=SUM+DX(J)*B(I,J)
80       W(I)=W(I)-SUM
X        OUTPUT W
X        OUTPUT IN
         IF(IN.LT.11)GO TO 500
         RETURN
         END
```

```
      SUBROUTINE LLTLC(R,W,X,AE,EFI)
C
C     CONVERTS GEOGRAPHIC COORDINATES TO LOCAL X,Y,Z
C     R(1),R(2),R(3) = LAT,LONG,ELEV OF LOCAL REF IN RADIANS AND METERS
C     W(1)= LAT,LONG,ELEV OF POINT TO BE CONVERTED
C     X(1),X(2),X(3) = EAST, NORTH, VERT FROM REFERENCE
C     AE = SEMI MAJOR AXIS IN METERS
C     EFI = 1/F INVERSE FLATTENING
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION A(3,3),RX(3),PX(3),X(3),R(3),W(3)
      F=1./EFI
      EE=F*(2.-F)
      BB=AE*(1.-F)
      COSLATR=DCOS(R(1))
      RADR=BB/DSQRT(1.-EE*COSLATR*COSLATR)
      PHIRG=DATAN((1.-EE)*DTAN(R(1)))
X     OUTPUT F,EE,BB,COSLATR,RADR,PHIRG
C
      A(1,1)=-DSIN(R(2))
      A(1,2)=DCOS(R(2))
      A(3,3)=DSIN(R(1))
      A(2,3)=DCOS(R(1))
      A(3,1)=A(2,3)*A(1,2)
      A(3,2)=-A(2,3)*A(1,1)
      A(2,1)=-A(1,2)*A(3,3)
      A(2,2)=A(3,3)*A(1,1)
      A(1,3)=0.
X     OUTPUT A
C
      RX(1)=A(1,2)*(RADR*DCOS(PHIRG)+R(3)*DCOS(R(1)))
      RX(2)=-A(1,1)*(RADR*DCOS(PHIRG)+R(3)*DCOS(R(1)))
      RX(3)=RADR*DSIN(PHIRG)+R(3)*DSIN(R(1))
X     OUTPUT RX
C
      ENTRY GEOTLC(W,X)
C
C     GEOTLC ENTRY USED FOR MULTIPLE CONVERSIONS OF POINTS USING THE
C     SAME REFERENCE.  BEFORE USING GEOTLC, AN INITIAL CALL OF LLTLC
C     MUST BE MADE TO INITIALIZE SUBROUTINE TO LOCAL REFERENCE
C
      COSLATP=DCOS(W(1))
      RADP=BB/DSQRT(1.-EE*COSLATP*COSLATP)
```

```
      PHIPG=DATAN((1.-EE)*DTAN(X(1)))
X     OUTPUT RADP,PHIPG
      PX(1)=DCOS(W(2))*(RADP*DCOS(PHIPG)+W(3)*DCOS(W(1)))
      PX(2)=DSIN(W(2))*(RADP*DCOS(PHIPG)+W(3)*DCOS(W(1)))
      PX(3)=RADP*DSIN(PHIPG)+W(3)*DSIN(W(1))
X     OUTPUT PX
C
      DO 20 I=1,3
      X (I)=0.
      DO 20 J=1,3
20    X (I)=X (I)+A(I,J)*(PX(J)-RX(J))
X     OUTPUT X
      RETURN
      END
```

```
      SUBROUTINE DEGRE (RAD,ISN,ID,IM,FS)
      DOUBLE PRECISION FS,RAD,DD,DM,FS,CON
      DATA CON/57.295779513082321/
      DD=CON*DABS(RAD)
      ID=DD
      DM=(DD-ID)*60.
      IM=DM
      FS=(DM-IM)*60.
      ID=ISIGN(ID,RAD)
      ISN=1H
      IF(RAD.LT.0.)ISN=1H-
      IF(DABS(60.-FS).GT..0001) RETURN
      FS=0.
      IM=IM+1
      IF(IM.NE.60)RETURN
      IM=0
      ID=ID+ISIGN(1,RAD)
      RETURN
      END
```

Degrees from angle in radians

```
FUNCTION RAFA(ISN,ID,IM,SEC)
DOUBLE PRECISION RAFA,SEC,CON,ANG
DATA CON/57.295779513082321/
ANG=ID+IM/60.+SEC/3600.
RAFA=ANG/CON
IF((ID.EQ.0).AND.(ISN.EQ.1H-))RAFA=-RAFA;RETURN
IF((ID.GT.0).AND.(ISN.EQ.1H-))RAFA=-RAFA
RETURN
END
```

RADIANS FROM ANGLE IN DEG, MIN, SEC

```
      FUNCTION NZUTM(ANG)
      DOUBLE PRECISION CON,ANG,DD
      DATA CON/57.295779513082321/
      DD=ANG*CON
      NZUTM=(DD+186.)/6.
      IF(NZUTM.EQ.0)NZUTM=1
      RETURN
      END
```

UTM ZONE FROM ANGLE OF LONG IN RADIANS

```
      SUBRØUTINE DMATINV(A,N,NR)
C
C       MATRIX INVERSIØN RØUTINE
C       INVERTS N BY N MATRIX IN A ARRAY
C     DIMENSIØN NR MUST BE EQUAL ØR GREATER THAN N+2
C
      IMPLICIT DØUBLE PRECISIØN (A-H,Ø-Z)
      DIMENSIØN A(NR,NR)
      DETERM=0.
      DØ 20 J = 1,N
20    A(N+1,J)=0.
      DØ 550 I = 1,N
      AMAX=0.
      DØ 105 J = 1,N
      IF(A(N+1,J)-1.)60,105,60
60    DØ 100 K = 1,N
      IF(A(N+1,K)-1.)80,100,740
80    IF(AMAX-DABS(A(J,K)))85,100,100
85    IRØW = J
      ICØLUM = K
      AMAX = A(J,K)
100   CØNTINUE
105   CØNTINUE
      A(N+1,ICØLUM)=A(N+1,ICØLUM)+1.
      IF (IRØW - ICØLUM) 140,260,140
140   DETERM = - DETERM
      DØ 200 L = 1,N
      SWAP = A(IRØW,L)
      A(IRØW,L) = A(ICØLUM,L)
200   A(ICØLUM,L) = SWAP
260   A(I,N+1)=IRØW
      A(I,N+2)=ICØLUM
      A(N+2,I)=A(ICØLUM,ICØLUM)
      DETERM=DETERM*A(N+2,I)
      A(ICØLUM,ICØLUM)=1.0
      DØ 350 L = 1,N
350   A(ICØLUM,L)=A(ICØLUM,L)/A(N+2,I)
380   DØ 550 L1 = 1,N
      IF (L1 - ICØLUM) 400,550,400
400   T = A(L1,ICØLUM)
      A(L1,ICØLUM)=0.
      DØ 450 L = 1,N
450   A(L1,L) = A(L1,L)-A(ICØLUM,L)*T
```

```
550   CONTINUE
      DO 710 I = 1,N
      L = N + 1 - I
      IF(A(L,N+1)-A(L,N+2))630,710,630
630   JROW=A(L,N+1)+.1
      JCOLUM=A(L,N+2)+.1
      DO 705 K = 1,N
      SWAP = A(K,JROW)
      A(K,JROW) = A(K,JCOLUM)
      A(K,JCOLUM) = SWAP
705   CONTINUE
710   CONTINUE
740   RETURN
      END
```

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LRPDS INTERIM TECHNICAL REPORT. APPENDICES,(U)

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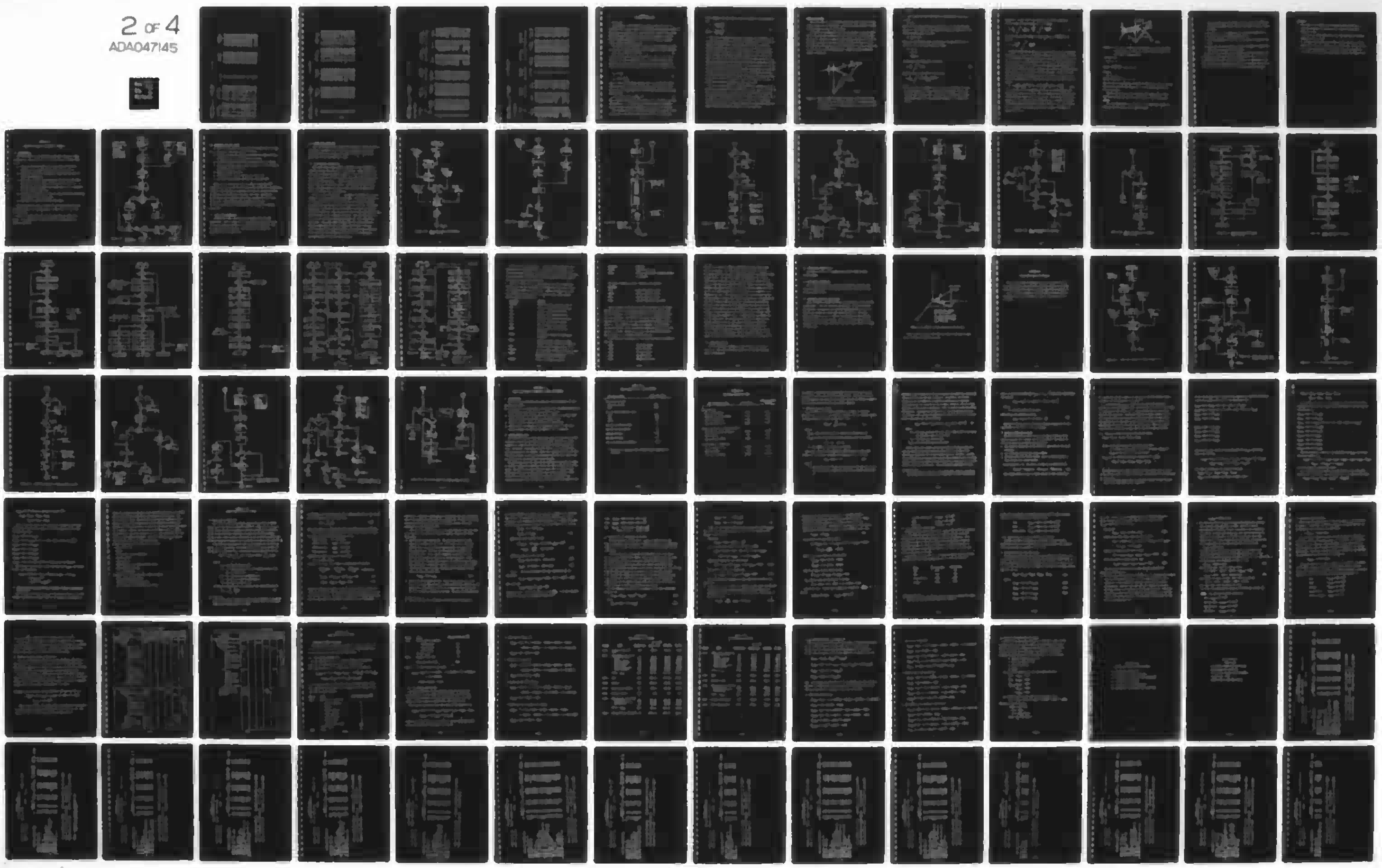
2 OF 4

ADA047145



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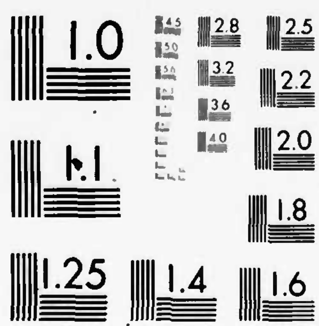

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

CLARKE 1866   A = 6,378,206.4 M   1/F = 294.978698
CENTRAL SCALE FACTOR =   .9996

LATITUDE D	M	SEC	LONGITUDE D	M	SEC	UTM ZONE	EASTING METERS	NORTHING METERS
+ 34	15	34.7420	- 96	2	43.1580	14	772075.8124	3794702.1723
+ 35	34	51.9020	- 96	34	19.5152	14	720000.0083	3940000.0014
+ 34	40	48.4967	- 96	35	55.3122	14	720000.0024	3839999.9993
+ 33	46	44.5442	- 96	37	26.9490	14	720000.0069	3740000.0001
+ 25	0	.0000	+ 7	0	.0000	32	298150.5076	2766279.1748
+ 84	0	.0000	+ 12	0	.0000	32	534996.3300	9328895.5101
+ 34	6	37.8300	-109	34	25.2340	12	631555.1610	3775132.6198
+ 34	6	36.5340	-109	34	25.1560	12	631557.7170	3775092.7274
- 80	0	.0000	- 14	52	3.7800	28	502564.5275	18881458.4577
+ 21	35	.0000	- 42	36	52.3800	23	746997.2940	2388460.8581
+ 84	0	.0000	+123	5	51.2300	51	501138.6343	9327985.0788
+ 34	52	31.7854	-111	23	54.2180	12	463589.9772	3859111.3734
+ 52	36	7.8531	-123	45	23.7832	10	448757.0142	5828069.0794
+ 45	58	59.1456	-163	25	58.9013	3	621374.3637	5093145.0959
+ 17	12	25.8631	- 76	24	59.9921	17	774755.8815	1904192.9796
+ 80	20	20.0000	+ 84	0	.0000	44	556184.1448	8920733.1898
- 38	56	35.5478	-177	45	52.1045	1	433747.9025	14310544.2947
+ 0	0	.0000	+ 3	0	.0000	31	500000.0000	.0000
+ 32	30	.0000	-114	40	.0000	11	719221.9445	3598068.9357
+ 33	29	32.0823	-112	0	31.8817	12	406279.6840	3706121.9902

CLARKE 1866 A = 6,378,206.4 M 1/F = 294.978698
CENTRAL SCALE FACTOR = .9996

UTM ZONE	EASTING METERS	NORTHING METERS	LATITUDE D	M	SEC	LONGITUDE D	M	SEC
12	406279.8000	3706122.0000	33	29	32.0827	-112	0	31.8772
12	406290.0000	3706085.0000	33	29	30.8846	-112	0	31.4681
12	631555.1600	3775132.6200	34	6	37.8300	-109	34	25.2340
12	631543.6220	3775276.2120	34	6	42.4960	-109	34	25.6060
12	631557.6800	3775093.1360	34	6	36.5473	-109	34	25.1572
12	631577.7480	3775093.1890	34	6	36.5399	-109	34	24.3741
14	720000.0000	3940000.0000	35	34	51.9020	- 96	34	19.5155
14	720000.0000	3840000.0000	34	40	48.4967	- 96	35	55.3123
14	720000.0000	3740000.0000	33	46	44.5442	- 96	37	26.9493
13	255165.4500	3994009.5400	36	3	42.0541	-107	43	5.7720
14	772075.8100	3794702.1700	34	15	34.7419	- 96	2	43.1581
11	719221.9400	3598068.9400	32	30	.0001	-114	40	.0002
10	225692.0000	13794711.1800	- 34	15	32.9224	-125	58	44.0166
30	500000.0000	.0000	0	0	.0000	- 3	0	.0000
42	625000.0000	16759832.0000	- 60	57	19.9284	71	18	29.3571
51	293100.0000	11111111.1100	- 10	2	48.4529	121	6	44.0059
60	800000.0000	4271.1100	0	2	18.9654	179	41	41.9800
11	682221.0000	7000000.0000	63	5	6.6140	-113	23	26.7097
16	500000.0000	500000.0000	4	31	25.8621	- 87	0	.0000
12	406279.6840	3706121.9902	33	29	32.0823	-112	0	31.8817

CLARKE 1866 A = 6,378,206.4 M 1/F = 294.978698
CENTRAL SCALE FACTOR = .9996

LOCAL REFERENCE

UTM ZONE	EASTING METERS	NORTHING METERS	LATITUDE D M SEC	LONGITUDE D M SEC
14	720000.0000	3840000.0000	34 40 48.4967	- 96 35 55.3123

UTM ZONE	EASTING METERS	NORTHING METERS	ELEVATION METERS	X METERS	Y METERS	Z METERS
14	721000.0000	3841000.0000	221.0000	1023.3934	975.6881	220.8282
14	725000.0000	3845000.0000	1001.0000	5117.5887	4878.9287	997.0027
14	750000.0000	3895000.0000	501.0000	31304.7243	54251.4114	191.9368
14	795000.0000	3955000.0000	488.0000	77727.4425	113102.1126	-993.0480
14	700000.0000	3800000.0000	763.0000	-20943.4272	-39512.0714	606.4633
14	713500.0000	3860000.0000	829.0000	-6019.6153	20148.4637	793.9254
14	640000.0000	3880000.0000	3200.0000	-79054.8141	41923.5310	2572.0146
14	722000.0000	3890000.0000	2900.0000	3199.6741	49949.3003	2702.2695
14	731000.0000	3920000.0000	521.0000	12920.4319	79697.4850	7.1130
14	788000.0000	3850000.0000	482.0000	68195.3092	8370.0637	112.2100
14	761000.0000	3821000.0000	2100.0000	40536.0246	-19970.3467	1940.3129
14	685000.0000	3841000.0000	3300.0000	-34979.9923	1835.4315	3203.9408
14	699000.0000	3775000.0000	499.0000	-22531.4620	-64478.4743	133.2032
14	689000.0000	3839999.0000	500.0000	-30989.5859	738.4426	424.7498
14	720001.0000	3840001.0000	1000.0000	1.0235	.9758	1000.0000
14	720000.0000	3840000.0000	100.0000	-.0000	.0000	100.0000
14	719000.0000	3750000.0000	82.0000	-3123.9758	-89931.1306	-553.6304
14	755000.0000	3833000.0000	5341.0000	34841.4816	-7836.3495	5241.3137
14	731000.0000	3840000.0000	982.0000	10995.9496	-262.3749	972.5320
14	720000.0000	3739000.0000	100.0000	-2381.0682	-100948.4157	-700.5925

CLARKE 1866 A = 6,378,206.4 M 1/F = 294.978698
CENTRAL SCALE FACTOR = .9996

LOCAL REFERENCE

UTM ZONE	EASTING METERS	NORTHING METERS	LATITUDE D M SEC	LONGITUDE D M SEC
14	720000.0000	3840000.0000	34 40 48.4967	- 96 35 55.3123

X METERS	Y METERS	Z METERS	UTM ZONE	EASTING METERS	NORTHING METERS	ELEVATION METERS
1023.3934	975.6881	220.8282	14	720999.9954	3840999.9945	221.0000
5117.5887	4878.9287	997.0027	14	725000.0000	3844999.9999	1001.0000
31304.7243	54251.4114	191.9368	14	749999.9994	3894999.9996	501.0000
77727.4425	113102.1126	-993.0480	15	252076.2362	3953560.4037	488.0000
-20943.4272	-39512.0714	606.4633	14	699999.9993	3800000.0007	763.0000
-6019.6153	20148.4637	793.9254	14	713500.0000	3859999.9998	829.0000
-79054.8141	41923.5310	2572.0146	14	640000.0008	3880000.0014	3200.0000
3199.6741	49949.3003	2702.2695	14	722000.0000	3889999.9995	2900.0000
12920.4319	79697.4650	7.1130	14	730999.9996	3919999.9991	521.0000
68195.3092	8370.0637	112.2100	15	238750.1656	3849200.6375	482.0000
40536.0246	-19970.3467	1940.3129	14	761000.0009	3821000.0008	2100.0000
-34979.9923	1835.4315	3203.9408	14	684999.9996	3841000.0003	3300.0000
-22531.4620	-64478.4743	133.2032	14	698999.9990	3775000.0011	499.0000
-30989.5859	738.4426	424.7498	14	688999.9997	3839999.0003	500.0000
1.0235	.9758	1000.0000	14	720001.0025	3840000.9979	1000.0000
-.0000	.0000	100.0000	14	720000.0000	3840000.0000	100.0000
-3123.9758	-89931.1306	-553.6304	14	718999.9998	3750000.0014	82.0000
34841.4816	-7836.3495	5241.3137	14	755000.0006	3833000.0005	5341.0000
10995.9496	-262.3749	972.5320	14	731000.0001	3840000.0000	982.0000
-2381.0682	-100948.4157	-700.5925	14	719999.9998	3739000.0016	100.0000

STOP 0

APPENDIX C
PROPAGATION CORRECTIONS

1. INTRODUCTION

The propagation correction procedure discussed in this appendix is a simplified version of that reported in the LRPDS Error Analysis dated 15 April 1971. The procedure is simplified to the degree that each of the 1800 possible range measurements made during a flight can be corrected individually if desired. Certain simplifying assumptions are discussed in the following paragraphs that allow the above conclusion to be made.

The National Bureau of Standard at Boulder, Colorado recommends (reference one) the use of a bi-exponential model for the refractivity of the atmosphere,

$$N(h) = D_s\, e^{-\delta(h-h_m)} + W_s\, e^{-\omega(h-h_m)} \qquad (1)$$

in which the first term is referred to as the "dry term", and the second is called the "wet term". In equation (1), h_m is the surface altitude in km above mean sea level at which the coefficients D_s and W_s are measured; the latter are determined from the Smith and Weintraub constants (reference two),

$$D_s = 77.6 \frac{P}{T}$$
$$W_s = 3.73 \times 10^5 \frac{e}{T^2} \qquad (2)$$

where P is the total atmospheric pressure in mb, T is the absolute dry bulb temperature (°K) and e is the partial pressure of water vapor in mb. The partial pressure of water vapor may be obtained from the psychrometric formula (reference two)

$$e = e_s' - P(T-T')\ (471 + 0.665) \times 10^{-6} \qquad (3)$$

where e_s' denotes the saturation vapor pressure in mb at the absolute wet-bulb tempterature, T'. It is assumed in this discussion that the measurements required to make an accurate determination of D_s and W_s will be available.

It is further assumed that reasonable estimates for the values of the dry and wet terms in the vicinity of the aircraft altitude can be made; from

this information, the scale factors δ and ω in equation (1) can be determined as

$$\delta = \frac{ln[D_s/D(h)]}{(h - h_m)}$$

$$\text{and } \omega = \frac{ln[W_s/W(h)]}{(h - h_m)} \qquad (4)$$

Given that the atmospheric refraction is modeled as a bi-exponential, what are the residual propagation errors caused by modeling errors? This question is answered in reference three. In that study, both horizontal and vertical refractive gradients were assumed and the effects on the value of the range correction were determined; the horizontal gradients were approximately 60 N-units per 80 km. The NBS people at Boulder suggest that this represents the worst case situation for typical locations around the globe. As many as five different vertical profiles were inserted into a computer program that evaluated the actual refractivity along each ray path between an aircraft at 6 km altitude and FO's located at various points on the ground. Assuming that this atmosphere could be represented in bi-exponential form, with the parameters in equation (1) known via two measurements, one made on the ground and one made at the aircraft altitude, the results showed that the rms variation in the range correction due to horizontal gradients was about 1 part in 10^5.

However, the above assumes that a measurement would be available in the aircraft; no such measurement will be available in the field. Reference four showed that if the refractivity at the aircraft (or any other arbitrary) altitude is estimated, rather than measured, then the loss in accuracy is about 1 part in 10^5 for every 10% error in the estimate. This error proves to be the dominant, residual error assuming that the surface measurement of refractivity is good to within 5% (typical radiosonde measurements are better than this).

CORRECTION PROCEDURE

It has been shown that the atmospheric refractivity can be modeled, with sufficient accuracy, as a bi-exponential. A sufficiently simple procedure to obtain the actual range correction is next described.

The effects of an inhomogeneous atmosphere were examined in reference three; there it was shown that inhomogeneities in the refractivity were averaged over the ray path. Specifically, large refractive gradients (including surface ducts) had very little effect on the range correction required; the range correction was sensitive to only the average index of refraction, $\bar{n}$. Therefore, a simplified procedure requires a means of determining $\bar{n}$. Assume the typical propagation geometry of Figure C-1.

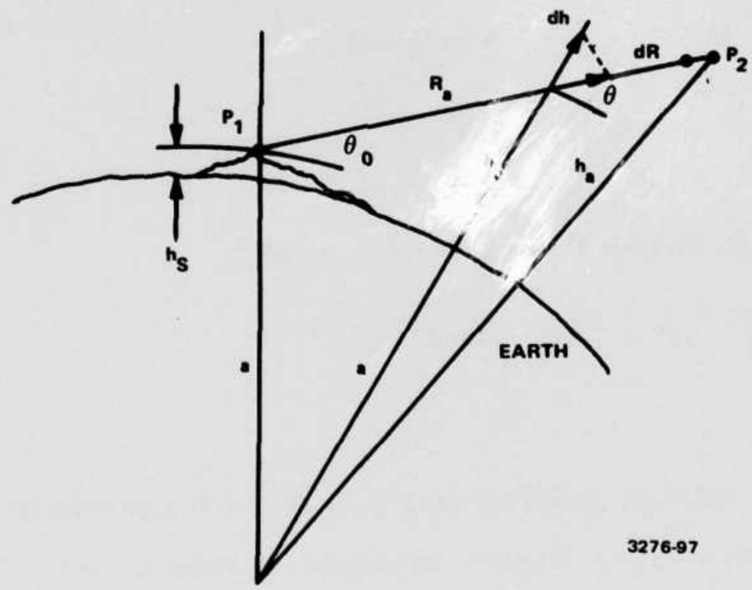

Figure C-1. Typical propagation geometry for which h_s in the surface altitude above sea-level, a is the earth's radius, θ_0 is the geometric angle of elevation, and θ is the angle between the ray P_1P_2 and the normal to the radius $a + h$.

It is seen that the actual path length, R_a, between points P_1 and P_2 is given by

$$R_a = \bar{v}\Delta T$$

where $\bar{v}$ is the average propagation velocity and ΔT is the existing time delay. However, $\bar{v} = c_o/\bar{n}$ where c_o is the propagation velocity in a vacuum and $\bar{n}$ is the average refraction index. Therefore

$$R_a = \frac{c_o}{\bar{n}} \Delta T = \frac{1}{\bar{n}} R_m ,$$

where R_m is the "measured" range. By definition, the range correction is the difference between the measured and actual ranges.

$$\begin{aligned} \Delta R &= R_m - R_a \\ &= (\bar{n}-1)\ R_a \\ &= \frac{(\bar{n}-1)}{\bar{n}}\ R_m \end{aligned} \tag{5}$$

By definition, the average index is given by*

$$\bar{n} = \frac{1}{R_a} \int_{P_1}^{P_2} N(R)dR \tag{6}$$

along the ray it is seen that $dh = dR \sin\theta$, so

$$\bar{n} = \frac{1}{R_a} \int_{h_s}^{h_a} \frac{[1 + N(h) \cdot 10^{-6}]}{\sin\theta} dh \tag{7}$$

---

*It is assumed that the geometric path P_1P_2 does not appreciably differ from the actual path which is slightly curved due to refractivity. It has been shown that these two paths differ in length by only centimeters for typical applications; consequently, the expression in equation (6) is essentially correct.

where $n(h) = 1 + N(h) \cdot 10^{-6}$; $N(h)$ is given by eqn (1) and is measured in N-units. Breaking the two integrals into two integrals,

$$\bar{n} = \frac{1}{R_a} \int_{h_s}^{h_a} \frac{dh}{\sin\theta} + \frac{10^{-6}}{R_a} \int_{h_s}^{h_a} \frac{N(h)dh}{\sin\theta}, \tag{8}$$

it is seen that the first integral is first equal to R_a. Therefore, eq (8) becomes

$$\bar{n} - 1 = \frac{10^{-6}}{R_a} \int_{h_s}^{h_a} \frac{N(h)dh}{\sin\theta} \tag{9}$$

It has been found that the average refractivity given by eqn (9) is remarkably insensitive to changes in θ. For instance, assuming a typical exponential profile for the atmosphere, and an aircraft altitude of 6 km, then the average refractivity, $\bar{N}$, is 244 N-units for a slant range of 10 km to the ground, 249 N-units at 100 km, and 255 N-units at 150 km; this error is a bias amounting to not more than 1 part in 10^5 over the ranges of interest. Therefore, eqn (9) may be calculated just once at some arbitrary θ, and the resulting $\bar{n}$ used for all ranges. The value of θ that leads to the simplest implimentation is 90° in which case R_a is equal to $h_a - h_s$. With these simplifications, and using eqn (1), eqn (9) can be integrated easily to obtain

$$\bar{n} - 1 = \frac{10^{-6}}{(h_a - h_s)}\left[\frac{D_s e^{\delta h_m}}{\delta}\left(e^{-\delta h_s} - e^{-\delta h_a}\right) + \frac{W_s e^{\omega h_m}}{\omega}\left(e^{-\omega h_s} - e^{-\omega h_a}\right)\right] \tag{10}$$

It is noted that all of the parameters in eqn (10) are readily determined (or assumed known) except for h_a and h_s. These two parameters can be determined from the data reduction process in the system computer. After the first two or three passes in the data reduction computer program, the x, y, z coordinates for each aircraft and ground station position is known relative to a plane, the origin of which is located at some altitude Z_o relative to sea level. The geometry is shown in Figure C-2.

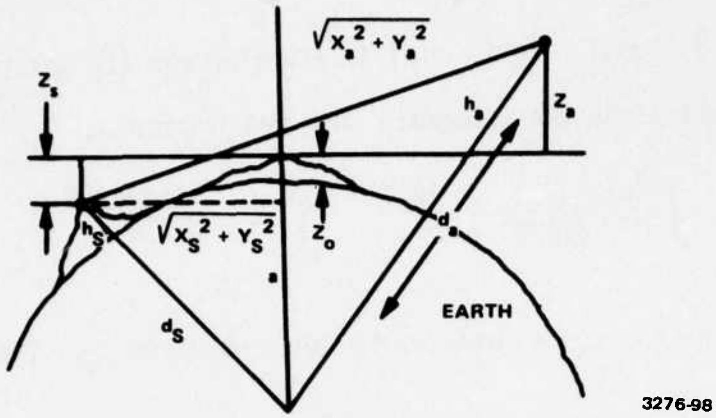

Figure C-2. Cross-section of earth showing coordinates of aircraft and ground station relative to a plane, the origin of which is located at an altitude of Z_o above sea level.

It is seen that

$$h_a = d_a - a$$

and $d_a^2 = (\sqrt{X_a^2 + Y_a^2})^2 + (Z_a + Z_o + a)^2$

Likewise, (11)

$$h_s = d_s - a$$

and $d_s^2 = (\sqrt{X_s^2 + Y_s^2})^2 + (Z_s + Z_o + a)^2$

Eqns (11) must be calculated once and stored for each aircraft position and each ground station location; this requires only 50 to 70 computer words plus the storage of Z_o and a.

With the calculations of eqn (11) completed, the average index is found immediately from eqn (10), and each range correction is found using eqn (5).

SUMMARY

The correction procedure described above is exceedingly easy to apply. The following steps are required in the computer program:

1. After the ground station and aircraft positions are correctly determined (except for propagation errors), eqns (11) are solved for each h_a and h_s and stored.
2. For each $R(J, K)$ in the computer program, eqn (10) is solved for $\overline{n} - 1$.
3. The range correction is determined using eqn (5).
4. Each range correction is subtracted from each $R(J, K)$ to obtain the true range.
5. Another pass in the data reduction process is initiated to determine the true aircraft and ground station positions.

The over-all accuracy of the range correction procedure has been shown to be approximately two parts in 10^5 with good radiosonde data (1 part in 10^5 error due to modeling errors, and 1 part in 10^5 error due to the approximation in $\overline{n}$). If the refractivity at some arbitrary altitude must be estimated, then an error of 1 part in 10^5 for each 10% error in the estimation will also be present.

REFERENCES

1. B. R. Bean, et al, "A World Atlas of Atmospheric Radio Refractivity", U.S. Department of Commerce Environmental Science Services Administration, Monograph 1, 1966.

2. B. R. Bean, E. J. Dutton, "Radio Meteorology", National Bureau of Standards Monograph 92, March 1, 1966.

3. E. J. Carlson, "Residual Propagation Errors Caused by Atmospheric Modeling Errors", TM #M-108, Systems Analysis Group, Motorola, Inc., February 15, 1971.

4. E. J. Carlson, "Implementation of Propagation Corrections Procedures for L.R.P.D.S.", TM #M-109, Systems Analysis Group, Motorola, Inc., March 3, 1971.

Appendix D

Scientific Field Data Reduction Program

1.0 INTRODUCTION

The flow diagram of the position calculation program is shown in Figure D-1. The program may be separated into five major tasks namely:

a. Parameter and data input which is processed to provide program control parameters and initialization data.

b. Coordinate conversion to change all input position data to local XYZ coordinates.

c. Batch data reduction which separates the data into batches and locates the local XYZ coordinates of the position reference set and position sets along with an error analysis of the calculated position.

d. Coordinate conversion to change the calculated XYZ coordinates into geographic lat-long or UTM.

e. Calculate any desired auxiliary positions.

The required input data is taken from the mission derived tape containing mission initialization and raw data from the position reference set.

Program initialization data may be overridden by input data cards. Also, program flow may be modified by proper choice of control parameters.

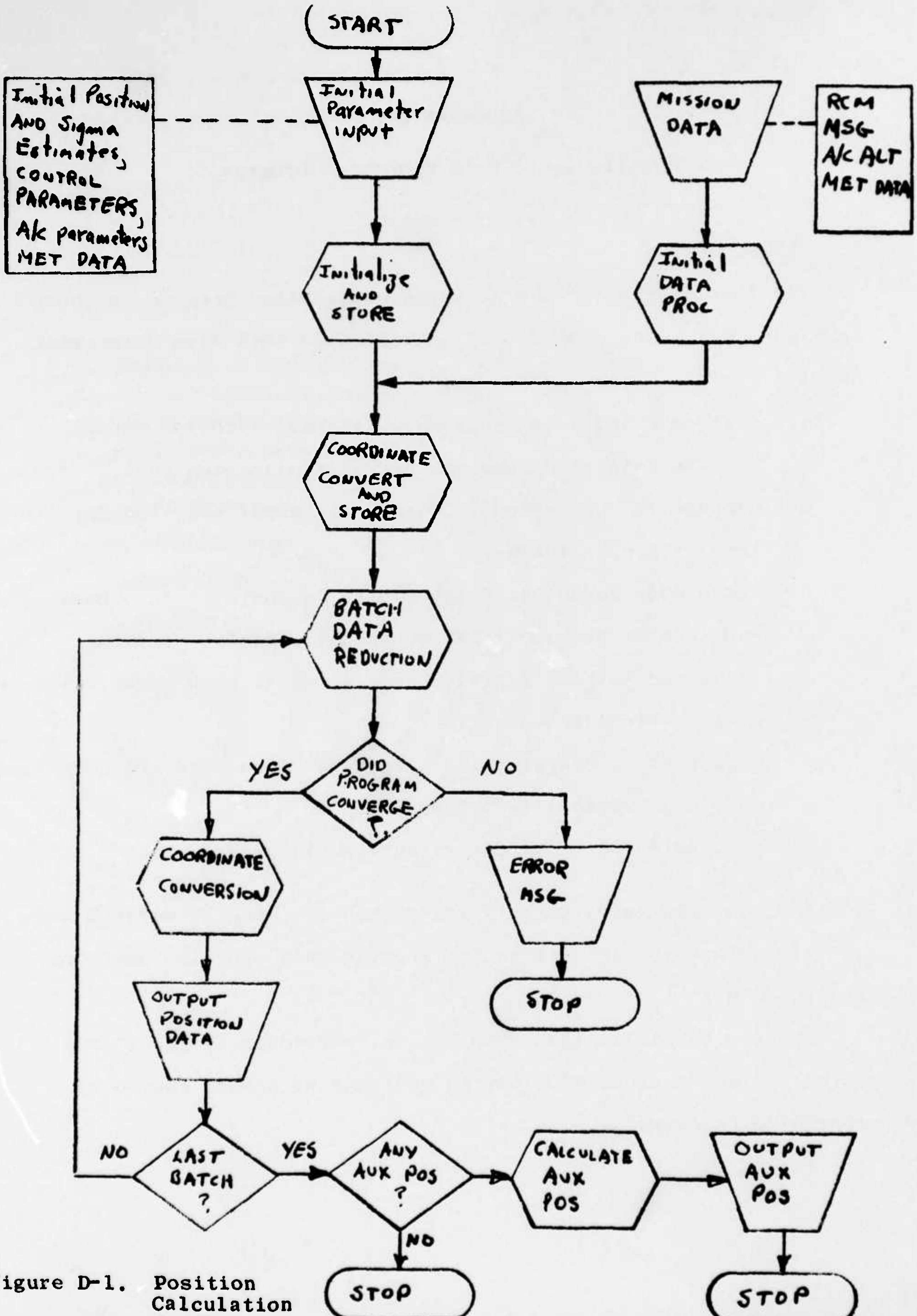

Figure D-1. Position Calculation Program

2.0 PARAMETER AND DATA INPUT

In order to initialize the data reduction program certain input data is required. The input tape will provide

a. Initial position set position estimates in either lat-long or UTM coordinates plus altitude in meters.

b. One sigma position estimates of location error in meters.

c. Flight parameters such as turning points or actual position estimates and max velocity.

d. Number of position sets.

e. Meterological data for propagation correction.

f. Raw data received from the position reference sets.

Proper arrays are set up in global memory to contain this information so that it can be accessed by the various data processing routines. The raw data is unpacked and stored in arrays according to category such as aircraft altitude, time tags, lost lock flags, meterological data, auxiliary point data, message data and range change data. Before storing the range change data, the coarse and fine words are combined and normalized into one 32 bit floating point word.

3.0 COORDINATE CONVERSION

All position input information is changed into local XYZ coordinates. This includes the initial position set estimates as well as all required aircraft initialization positions that may be called out by the program. The coordinate conversion is described fully in Appendix B.

4.0 BATCH DATA REDUCTION

The flow diagram for the Batch Data reduction is given in Figure D-2 pages 1 through 8, with a detailed flow diagram of the Subroutine REDUCE shown in Figure D-3 pages 1 thru 7. This is the major part of the data reduction task.

4.1 FLOW DIAGRAM DESCRIPTION

The input range change numbers represent one way propagation time differences from the initial measurement. These numbers are examined for blanks representing data drop outs and parity errors. This information is utilized along with the lost lock flag data to arrive at a lost data matrix where 1 represents a good data point and 0 indicates a blank data point. All bad data is set to zero value. The data point preceding a lost lock flag is considered bad in arriving at the lost data matrix.

A test of the lost data matrix is made to determine the maximum number of aircraft location positions KMAX. The data is compacted to close up any blanks created by deletion of aircraft positions not satisfying the minimum station visibility criteria. An average propagation correction factor is utilized to arrive at an average propagation velocity. This velocity is used to scale the range change times to range change distances in meters. The time tag vector is converted to real time utilizing the input A/C times versus time tag number. The range change measurements are tested against a maximum number derived from multiplying the aircraft velocity times the measurement time difference. Any range change distances (RCM) exceeding this maximum are deleted and the lost data matrix and KMAX updated to include this deletion.

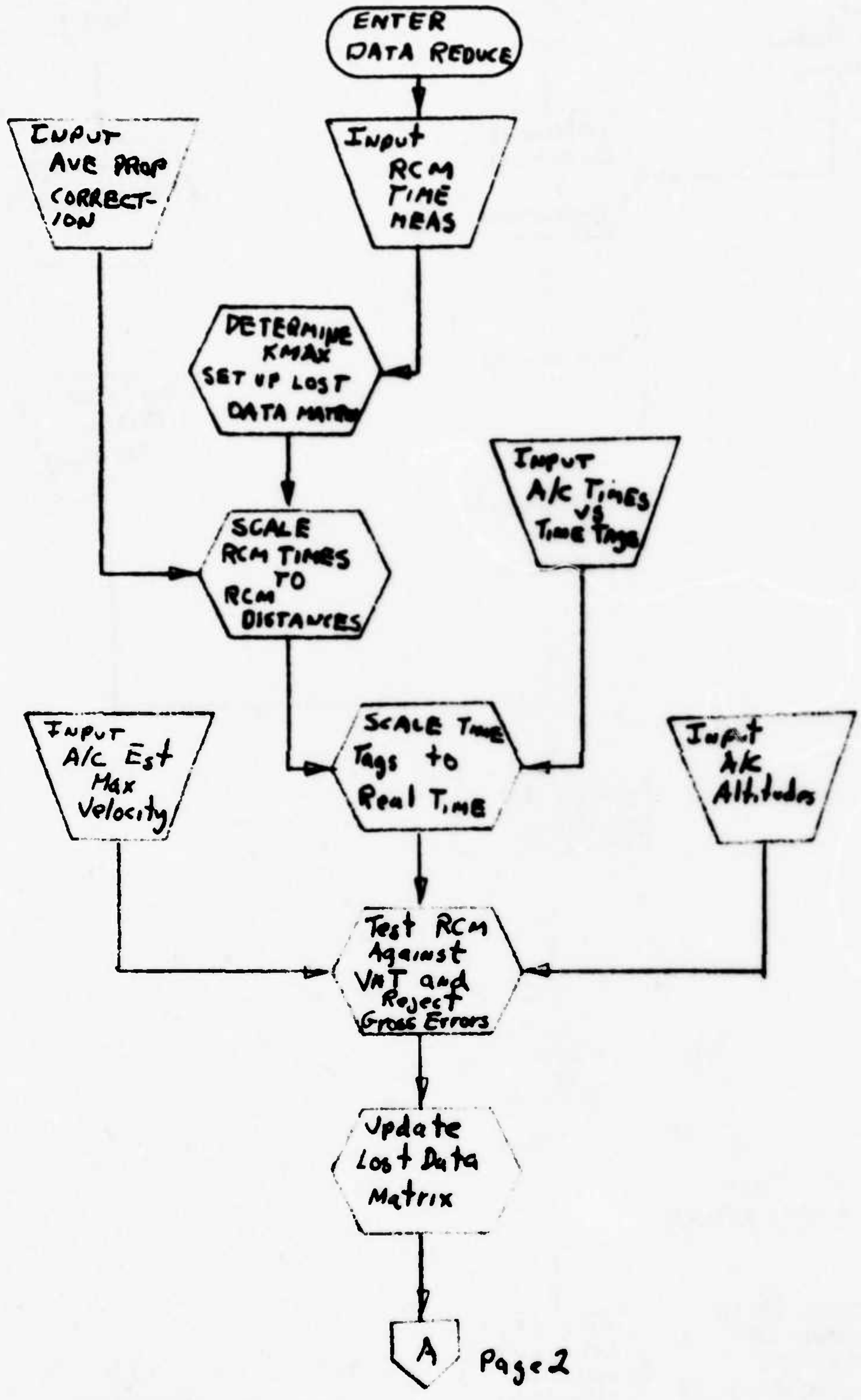

Figure D-2. Batch Data Reduction Diagram (Page 1 of 8)

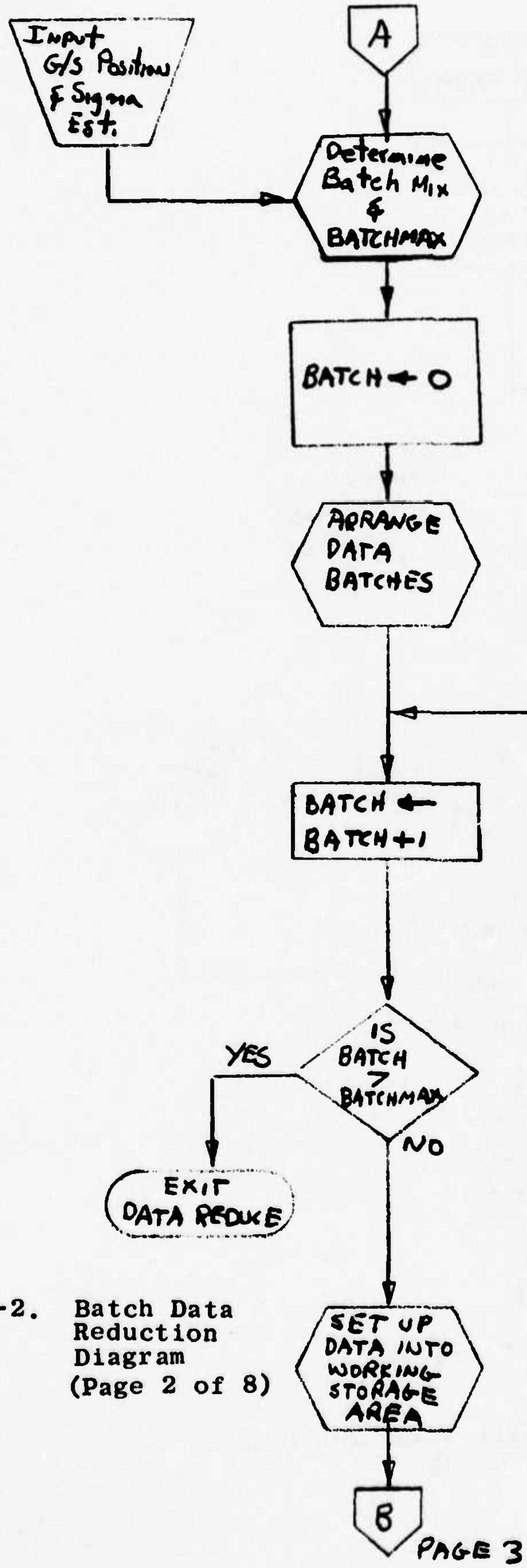

Figure D-2. Batch Data Reduction Diagram (Page 2 of 8)

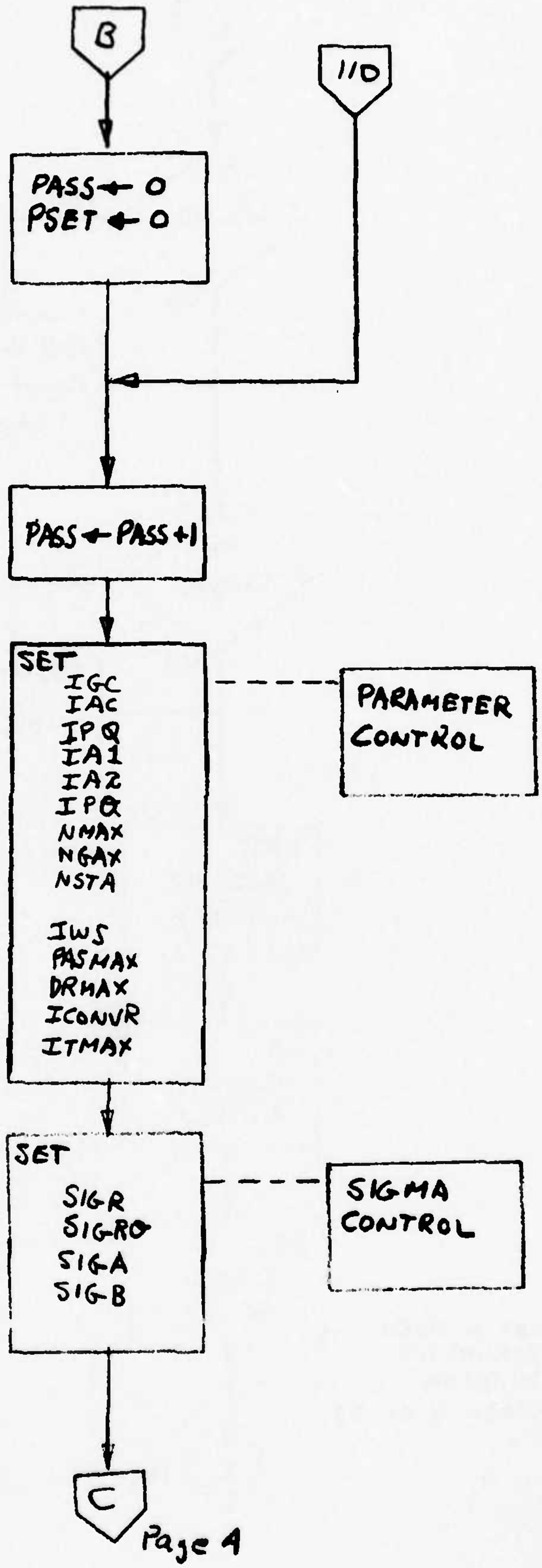

Figure D-2. Batch Data Reduction Diagram (Page 3 of 8)

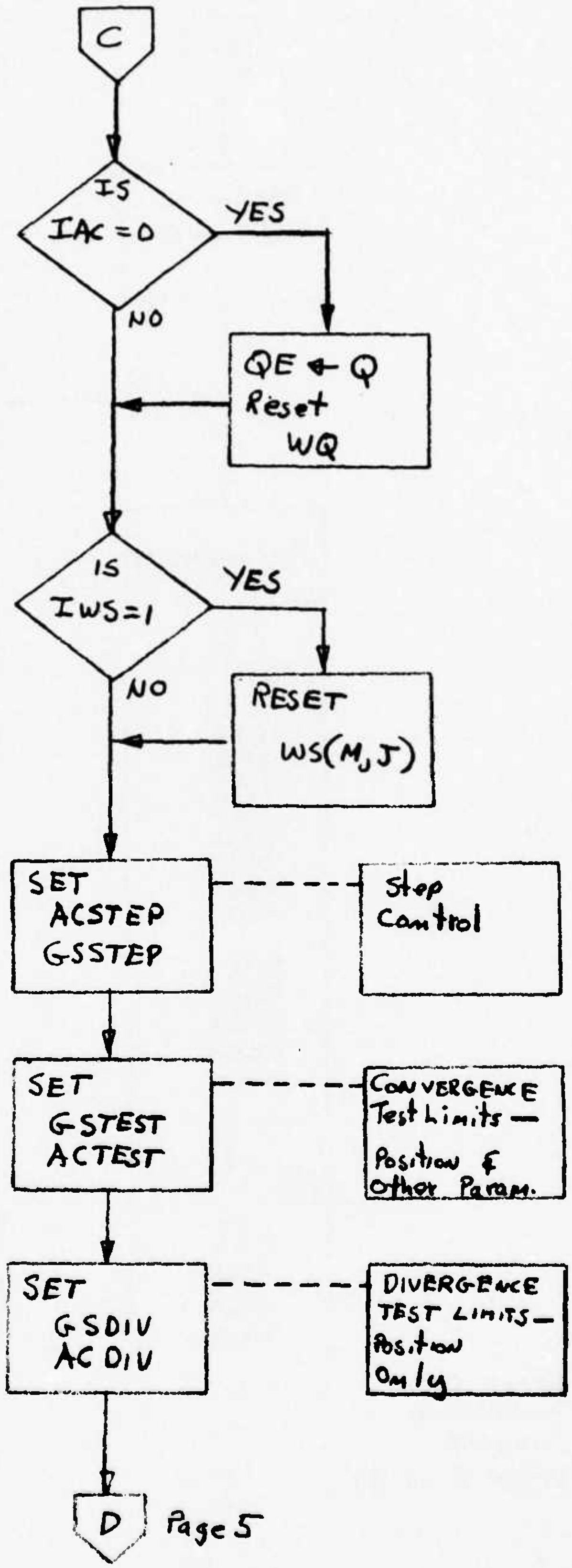

Figure D-2. Batch Data Reduction Diagram (Page 4 of 8)

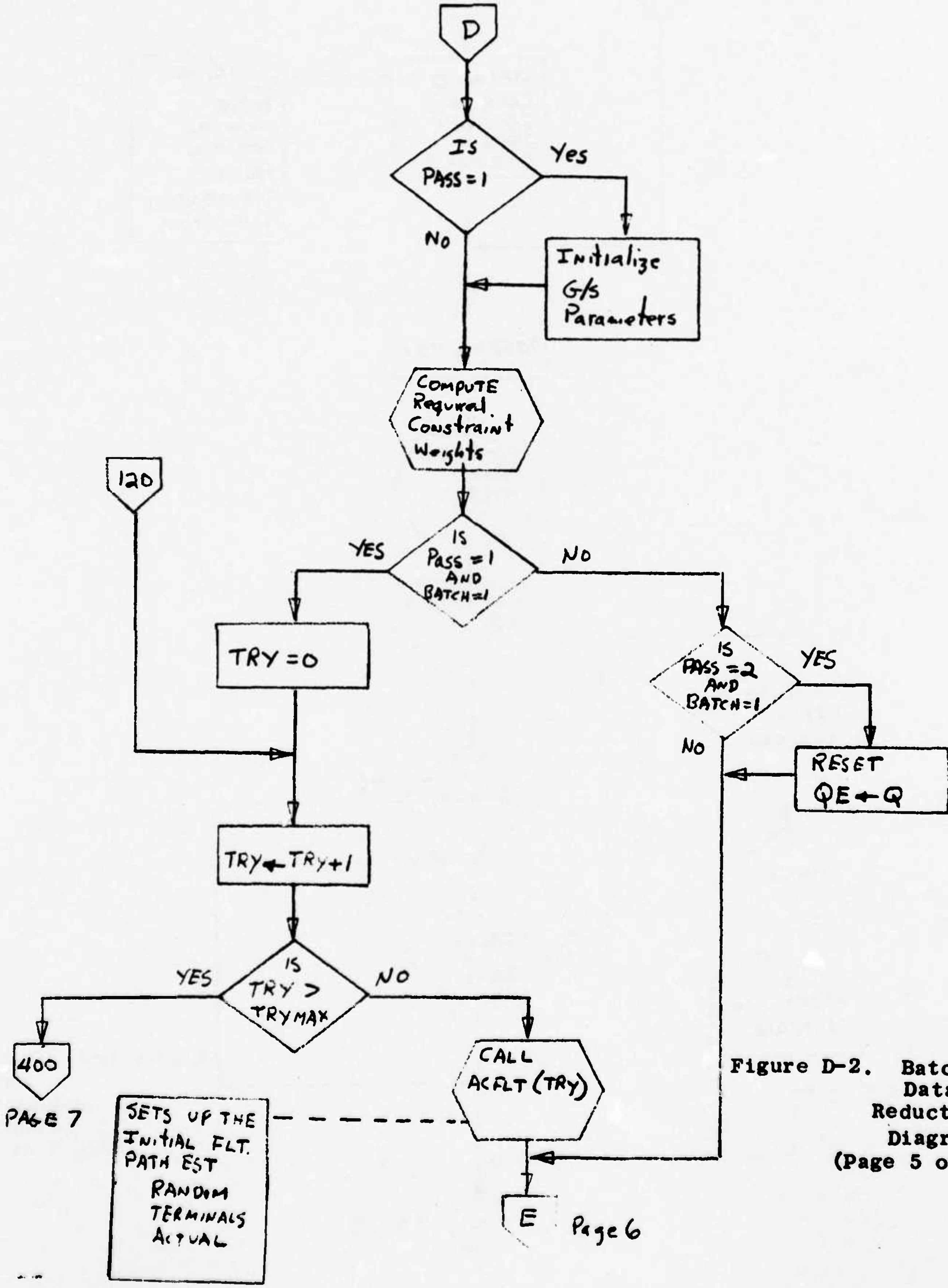

Figure D-2. Batch Data Reduction Diagram (Page 5 of 8)

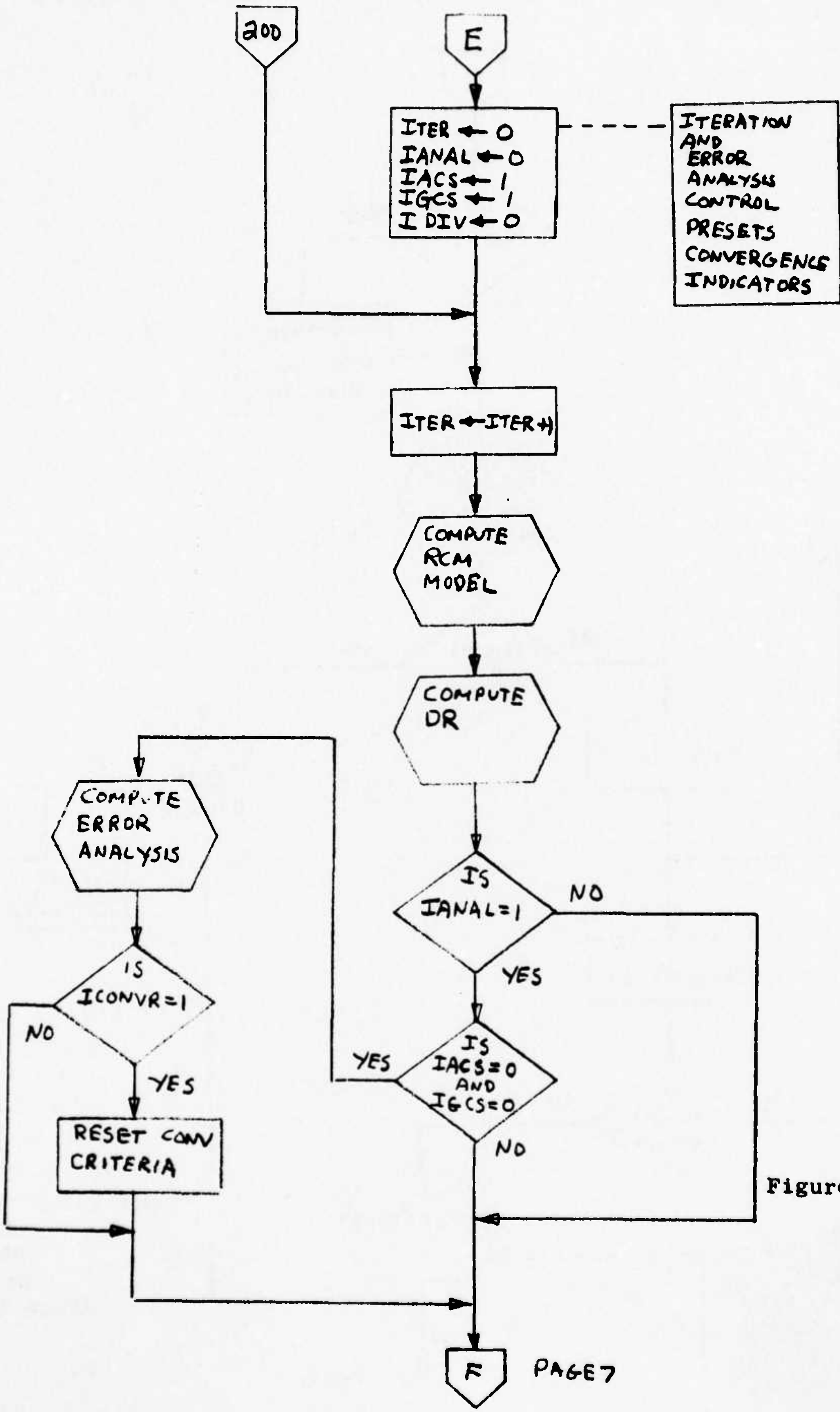

Figure D-2. Batch Data Reduction Diagram (Page 6 of 8)

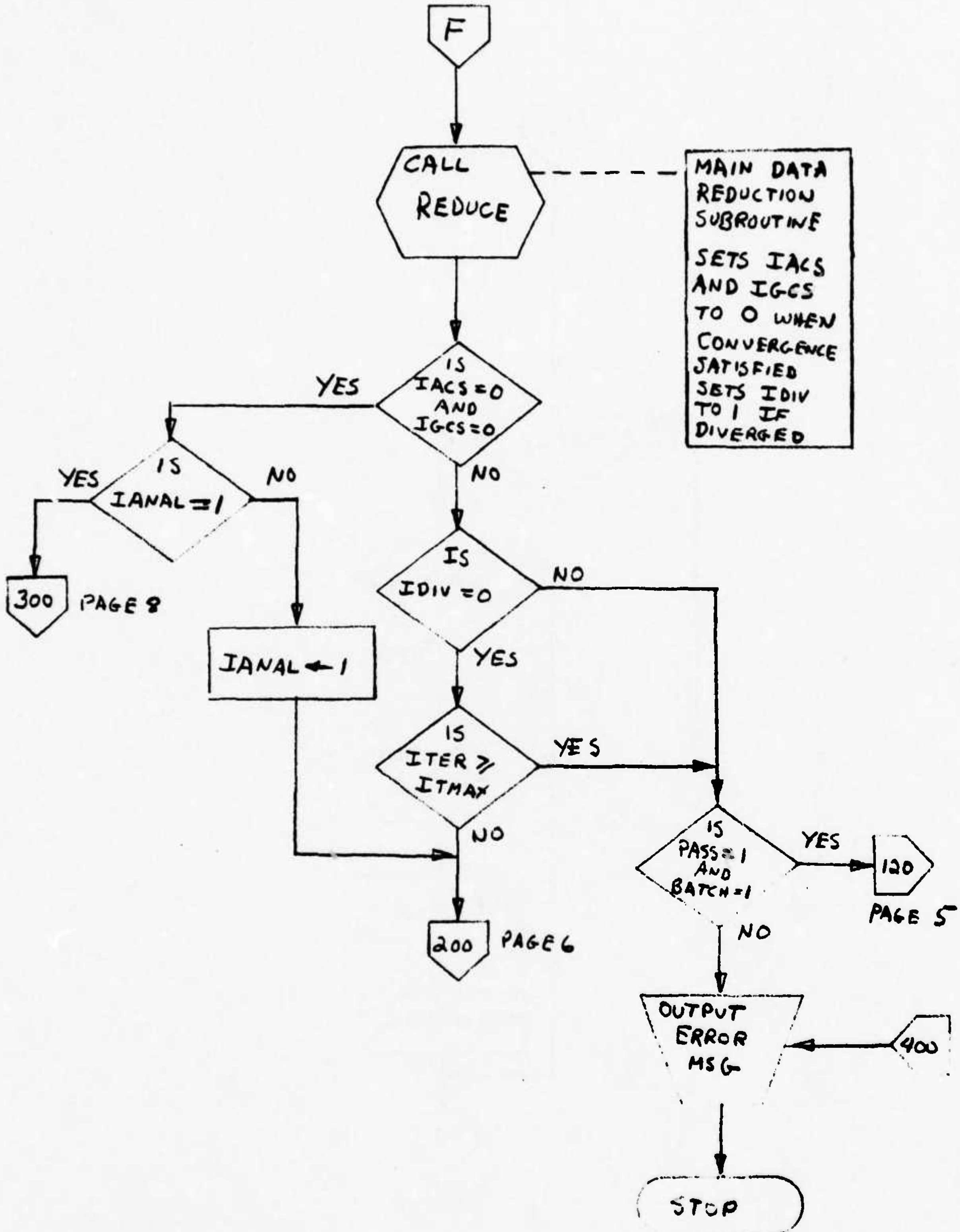

Figure D-2. Batch Data Reduction Diagram (Page 7 of 8)

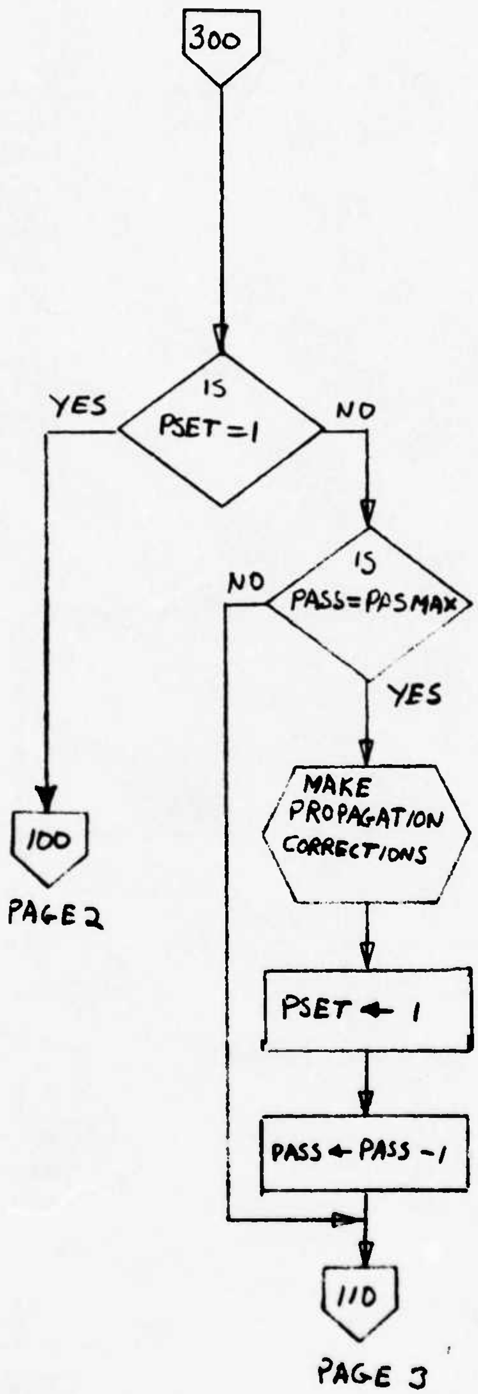

Figure D-2. Batch Data Reduction Diagram (Page 8 of 8)

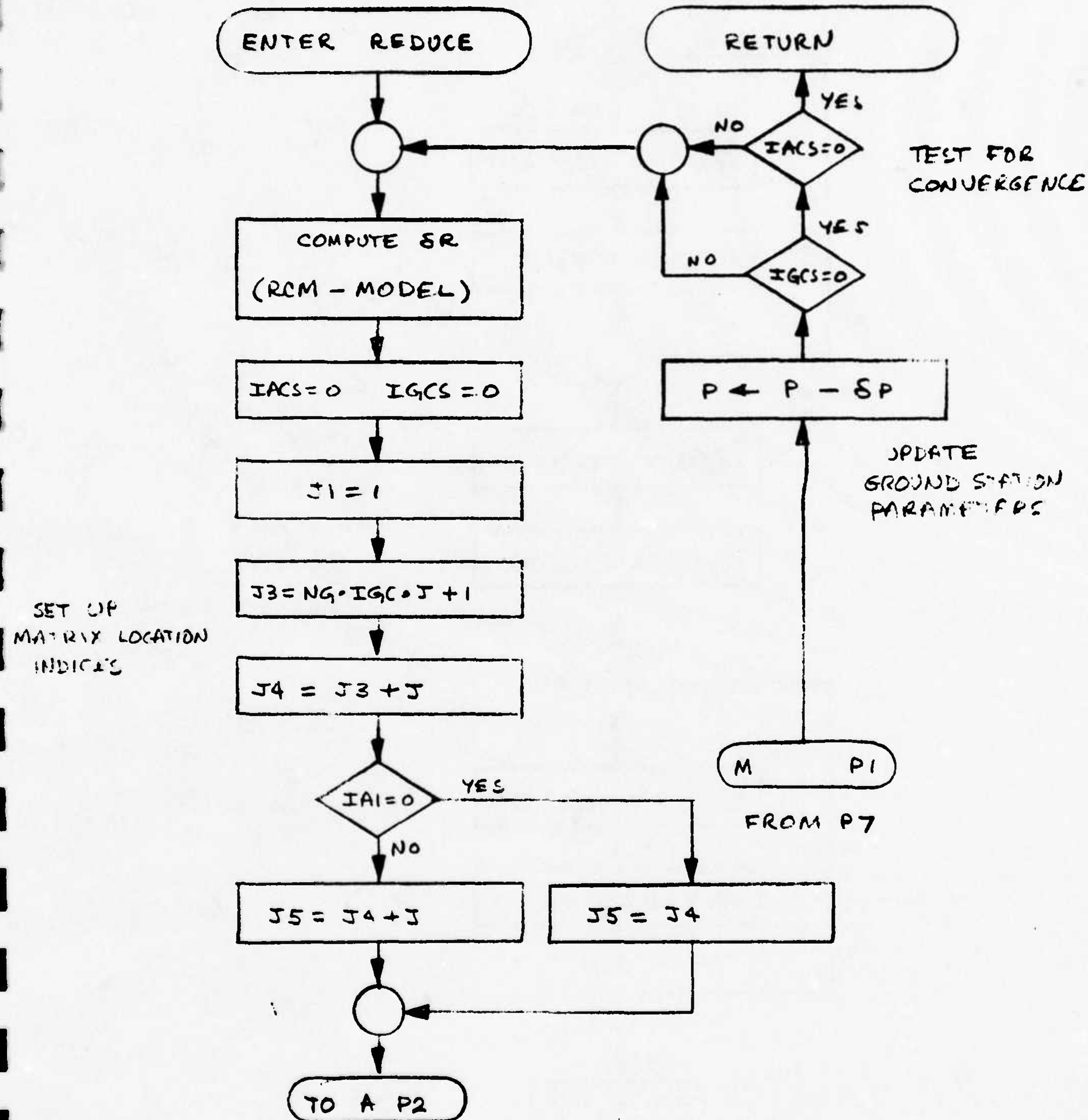

Figure D-3. Subroutine Reduce Diagram (Page 1 of 7)

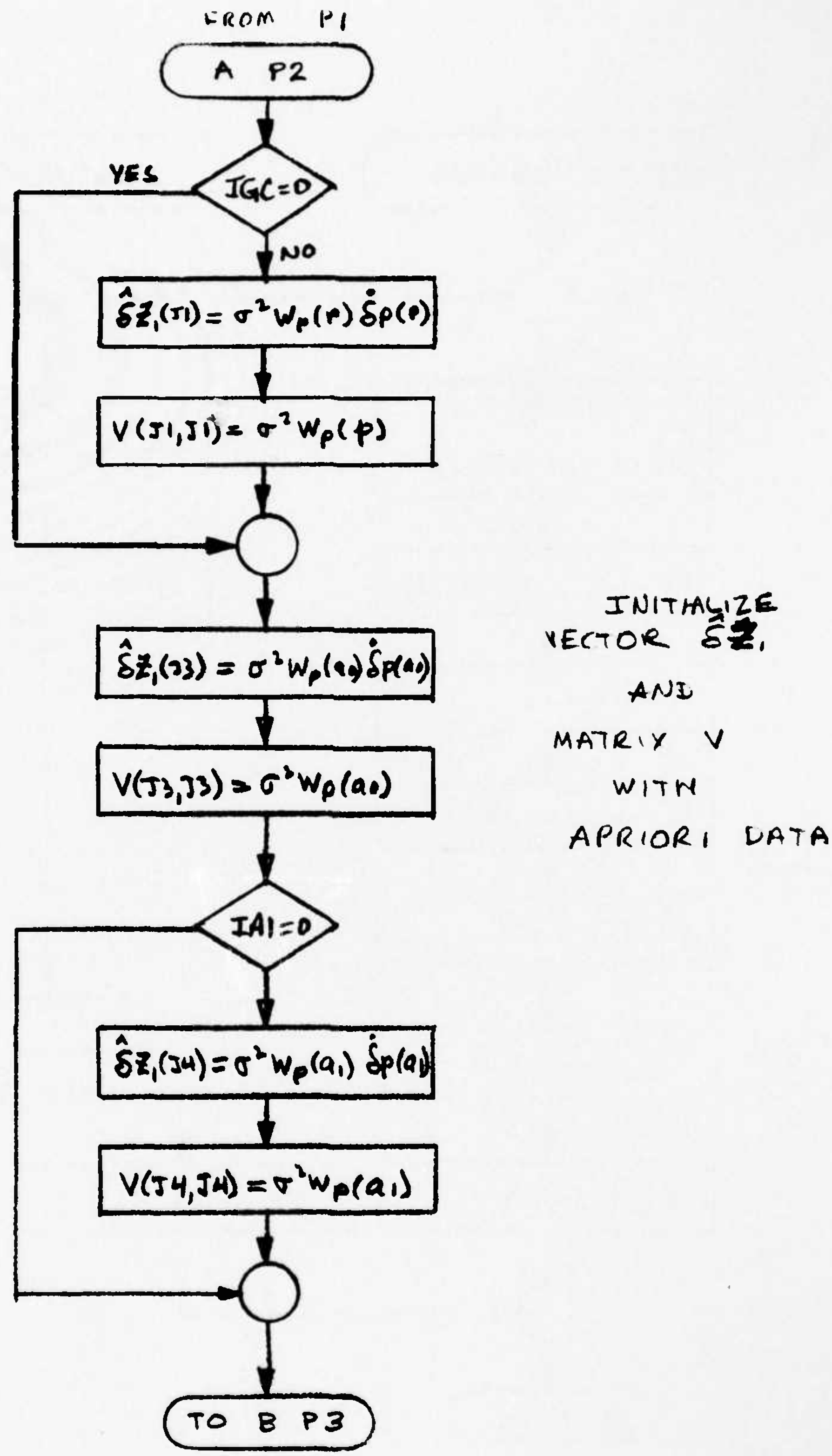

Figure D-3. Subroutine Reduce Diagram
(Page 2 of 7)

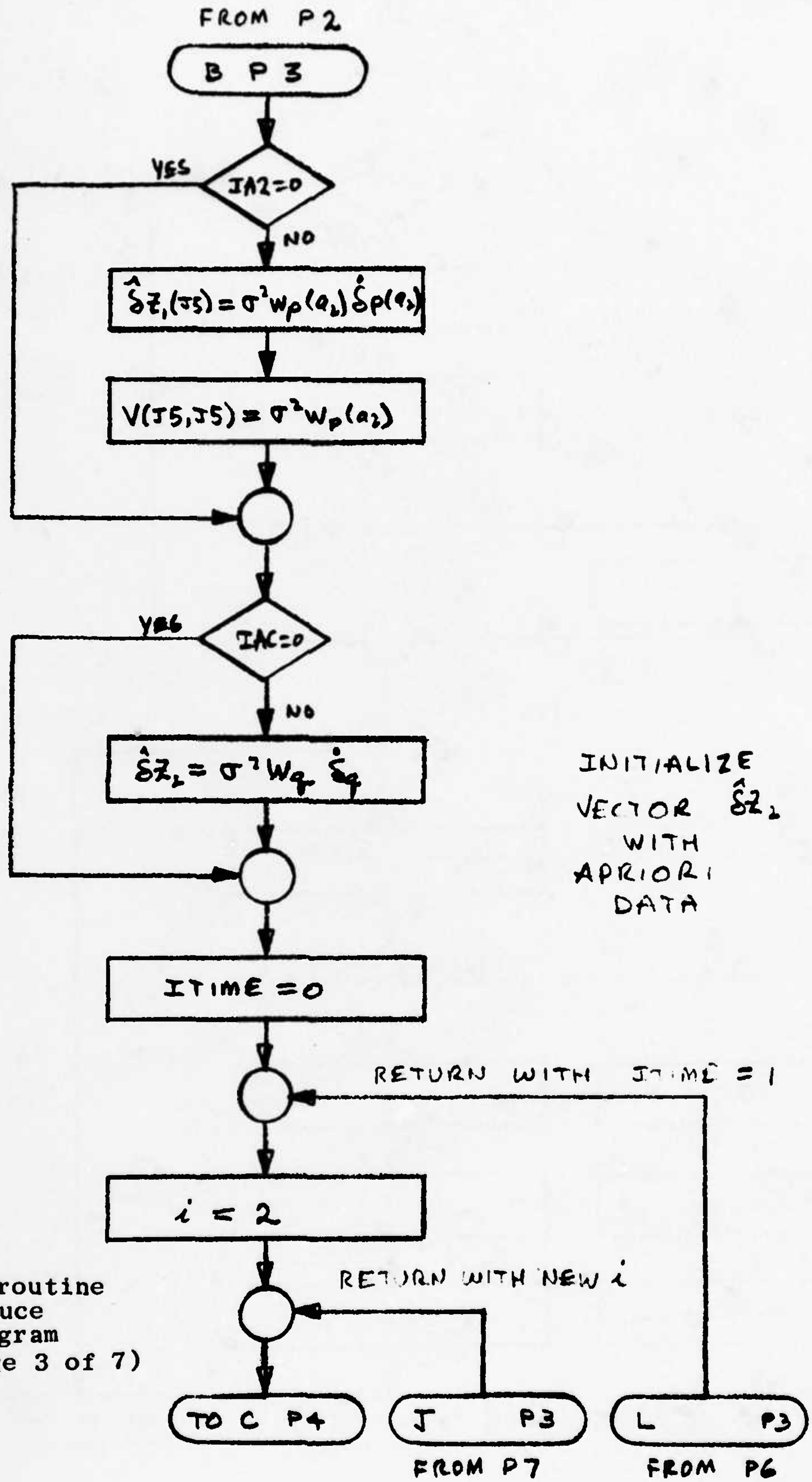

Figure D-3. Subroutine Reduce Diagram (Page 3 of 7)

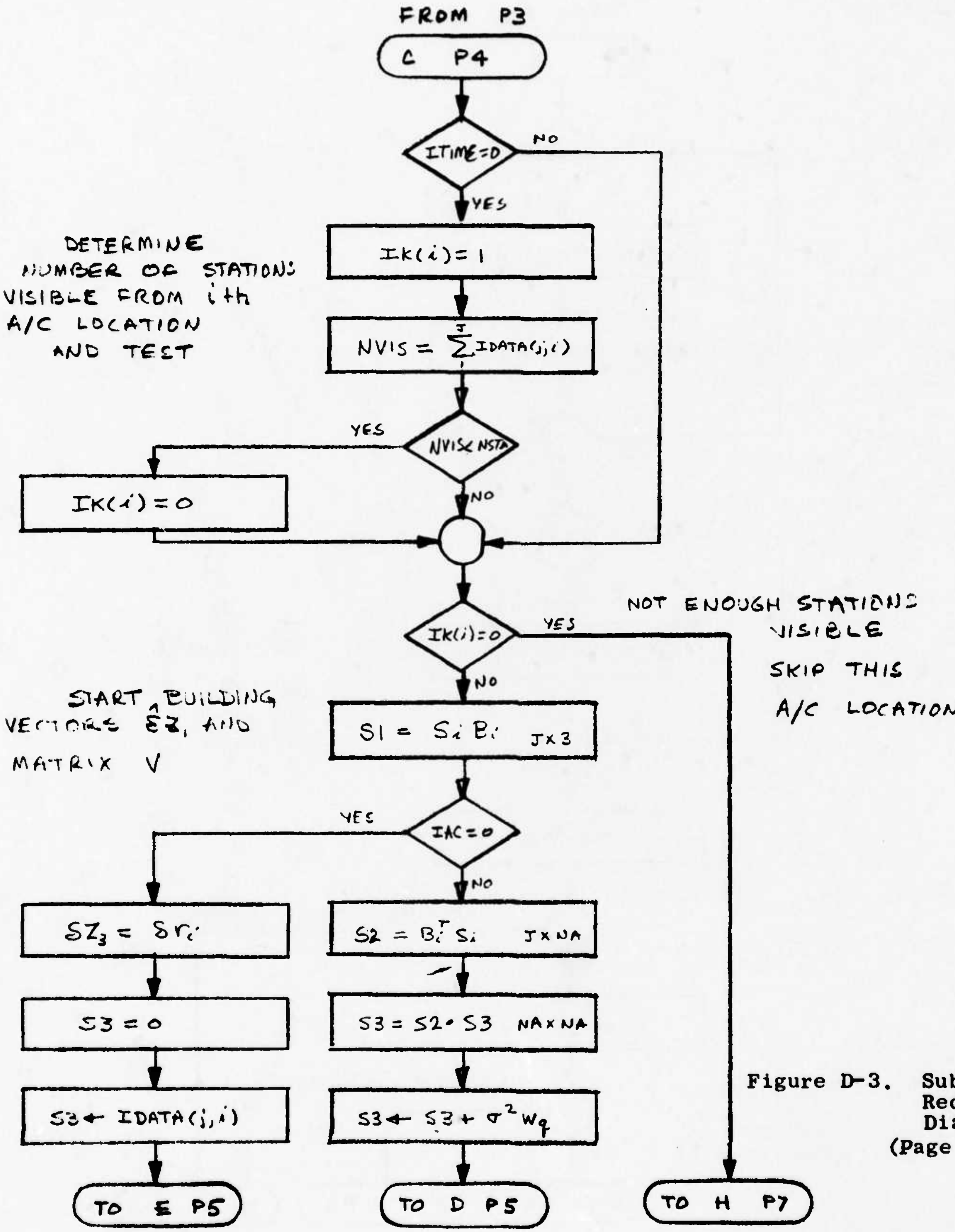

Figure D-3. Subroutine Reduce Diagram (Page 4 of 7)

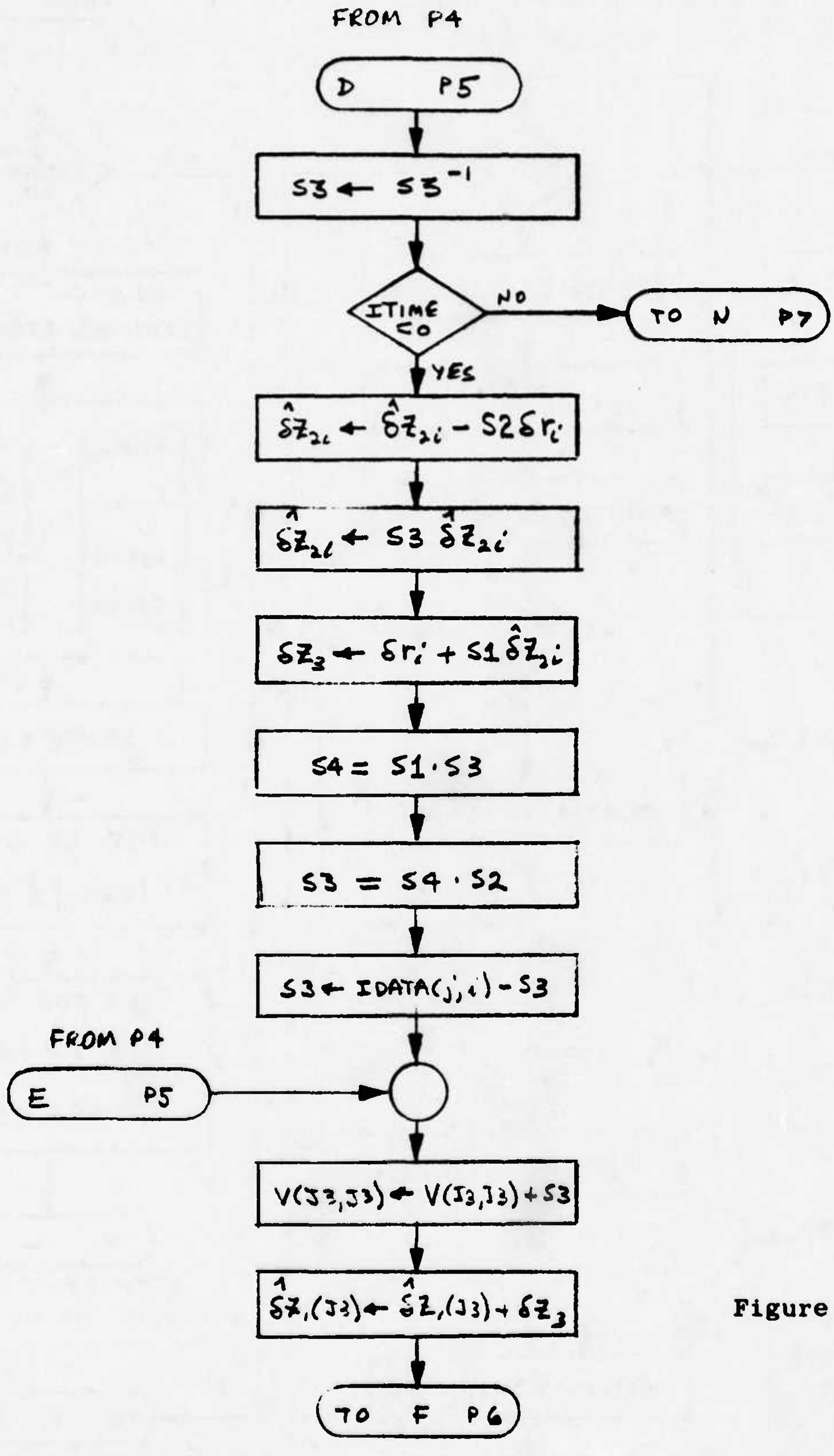

Figure D-3. Subroutine Reduce Diagram (Page 5 of 7)

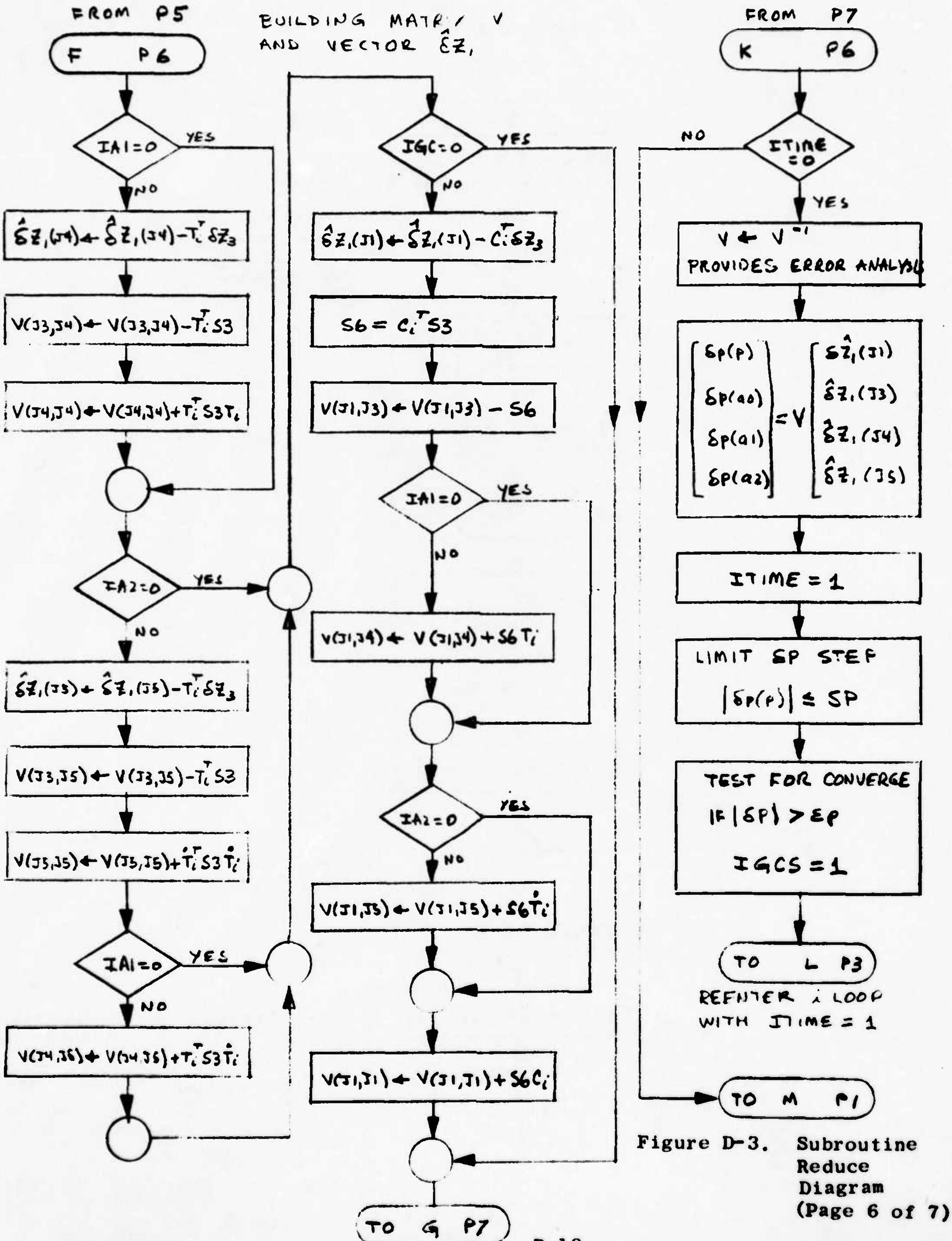

Figure D-3. Subroutine Reduce Diagram (Page 6 of 7)

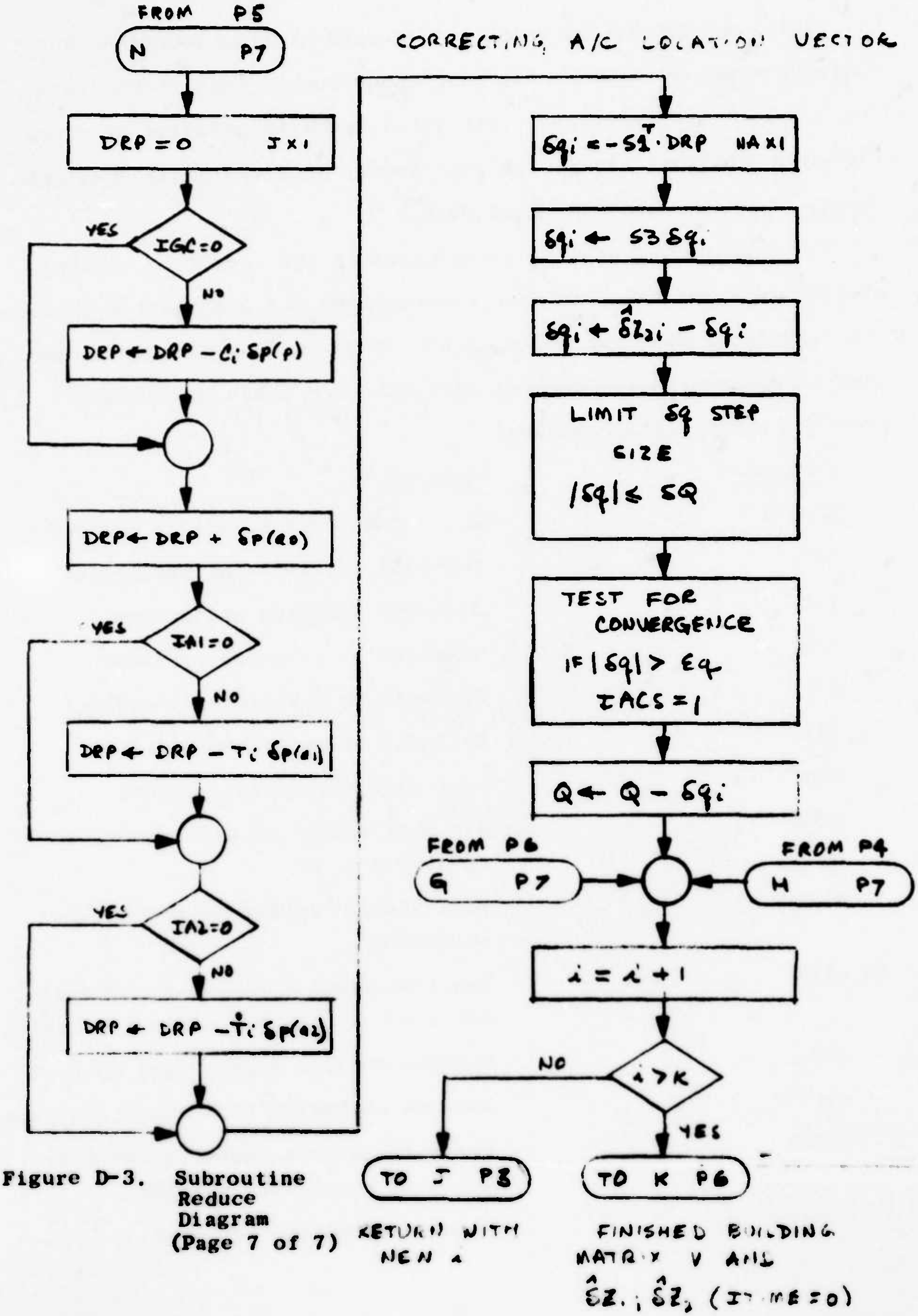

Figure D-3. Subroutine Reduce Diagram (Page 7 of 7)

Utilizing the lost data matrix, ground station locations and position error estimates, the data reduction is partitioned into batches for data reduction. The first batch is selected by choosing the prime stations along with the closest geographically scattered locations having the most good data.

The batch input data is transferred to the reduction working storage area and the data pass control PASS and propagation correction indicator PSET are set to zero. PASS is incremented and the pass dependent program control variables are set. The integer program control variables are.

Variable	Control
BOGMAX	Bogus data edit iteration control
IGC	Position set location estimation
IAC	Aircraft location estimation
IPQ	Quantity of progress printout
IA1	Estimate PS oscillator frequency
IA2	Estimate PS oscillator drift
IPO	Pass dependent print control
NMAX	Aircraft number of dimensions estimated
NGAX	Position set number of dimensions estimated
NSTA	Required minimum number of ground stations visable at each A/C location
IWS	Unknown station sigma reset control
PASMAX	Maximum number of data reduction passes
DRMAX	Max diff between computed and actual RCM data bogus data editing
ICONVR	Reset convergence criteria

Variable	Control
IBOGIE	Bogus data editing
ITMAX	Maximum iterations of REDUCE without convergence

The error estimates are set. These are as follows:

Variable	
SIGR	Range Measurement error
SIGRO	Initial range est error
SIGA	Initial freq est error
SIGB	Initial freq drift est error.

A test is made on IAC and if aircraft positions are not being estimated, the aircraft estimated positions are set equal to the current locations. The parameter IWS controls resetting the position set variances. The maximum step sizes, convergence and divergence test limits are set and ground station parameters set if PASS = 1. The constraint weights are computed. On the first pass of the first batch, first try aircraft flight positions are placed in array Q and QE. On the second pass, the estimated positions QE is equated to the present computed position.

After aircraft initialization, the following control parameters are set.

ITER	Iteration number
INAL	Error analysis
IACS	A/C convergence
IGCS	PS convergence
IDIV	REDUCE divergence

The iteration counter ITER is incremented and the range change model is computed. The error vector DR is computed from the difference between the range change measurements and computed range change values. The main data reduction subroutine is entered. Three control variables are set in this subroutine which control program flow upon exit from the routine. After first pass through REDUCE, with proper convergence the error analysis IANAL parameter is set to 1 which causes the error analysis to be computed. If ICONVR is set to 1, the convergence criteria may be reset before calling REDUCE a second time. With successful exit from REDUCE the bogus data control IBOGIE is tested. If bogus data editing is directed, this task is performed resetting last data matrix if required and reiterating through REDUCE. After successful data editing, a test of propagation correction control variable PSET and maximum pass PASMAX is made. If PASS is equal to PASMAX and PSET is equal to 0, the propagation correction is made and the program recycled thru the last pass to refine the positions. Successful convergence of REDUCE with no detected bogus data points causes the program to return to the beginning to pick up the next batch for processing. For all batches after the first batch, the aircraft positions are held fixed by setting IAC to 0.

4.2 SUBROUTINE REDUCE

The flow diagram of REDUCE is shown in Figure D-3 pages 1 through 7. For a detailed description of the process involved refer to Appendix A.

4.3 PROPAGATION CORRECTIONS

Appendix C details the propagation correction methods used in the program.

4.4 COORDINATE CONVERSION

The coordinate conversion routine is reentered to convert the local XYZ coordinates to Lat-Long and UTM before printing out the results of each batch.

5.0 AUXILIARY POSITION CALCULATION

After successful completion of the data reduction a test is made to determine if any aux positions are desired. If some positions are required, the position set location requesting the position is used as the origin of a local XYZ coordinate system. In other words the point X = 0, Y = - and Z = 0 correspond to the Lat-Long and Elevation of the PS location. The X Y Z of the AUX point is computed using the range, with elevation and azimuth angles as shown in Figure D-4.

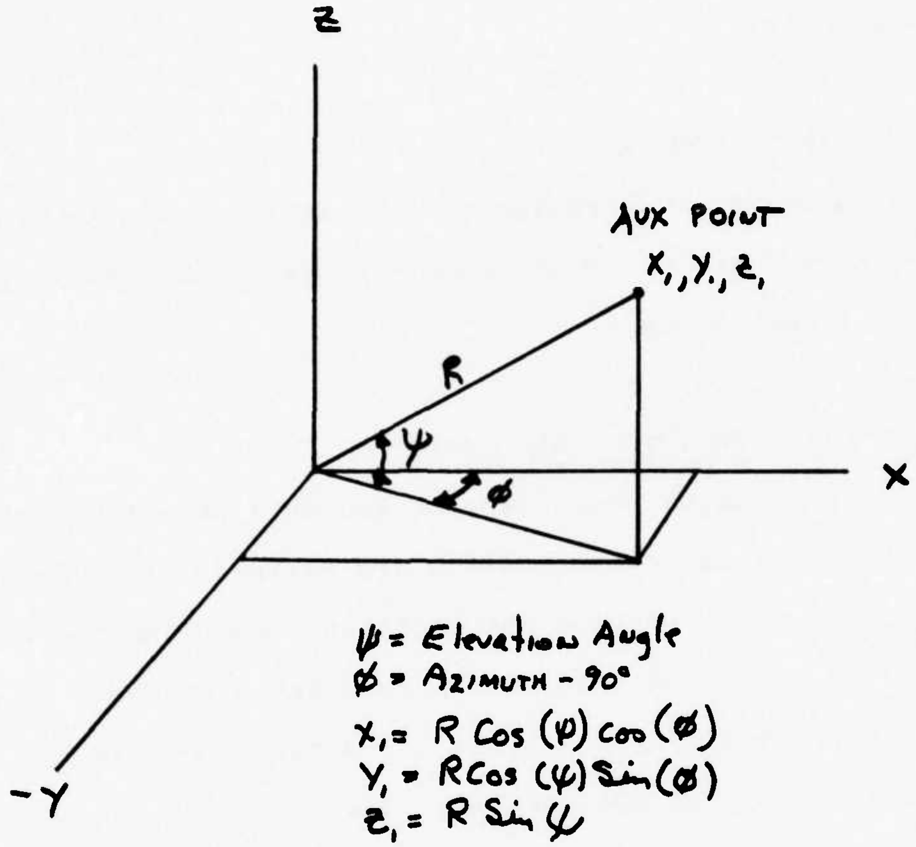

Figure D-4. Aux Point Local Coordinate Calculation

These local coordinates are then converted to Lat-Long or UTM by the coordinate conversion routine.

APPENDIX E

FIELD DATA REDUCTION PROGRAM

With the exception of operator controlled program flow and bogus data editing, the field data reduction program is the same as the scientific data reduction program described in Appendix D.

A detailed flow diagram of the field data reduction portion reflecting these modifications is shown in Figure E-1, pages 1 through 8.

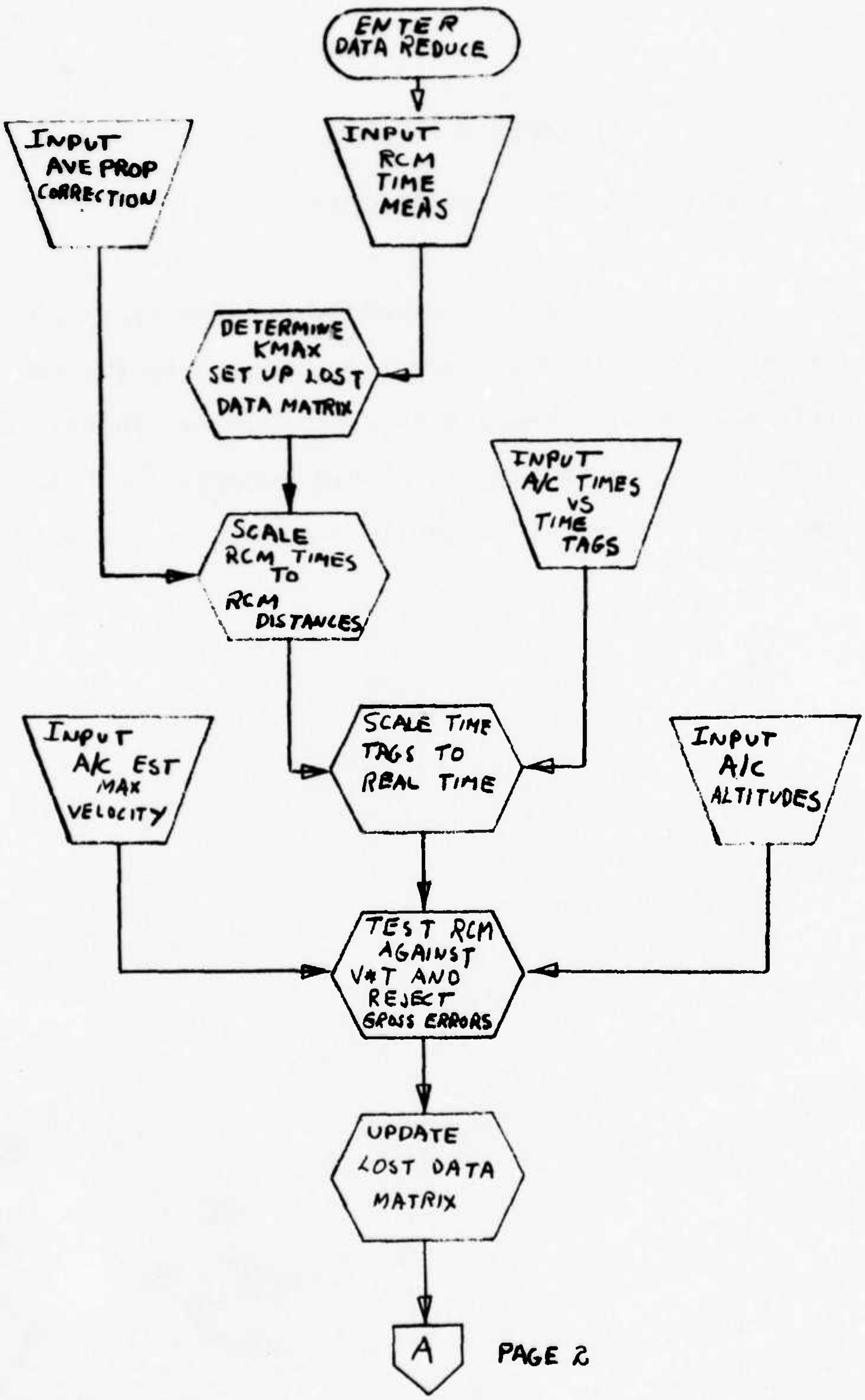

Figure E-1. Field Data Reduction Program (Page 1 of 8)

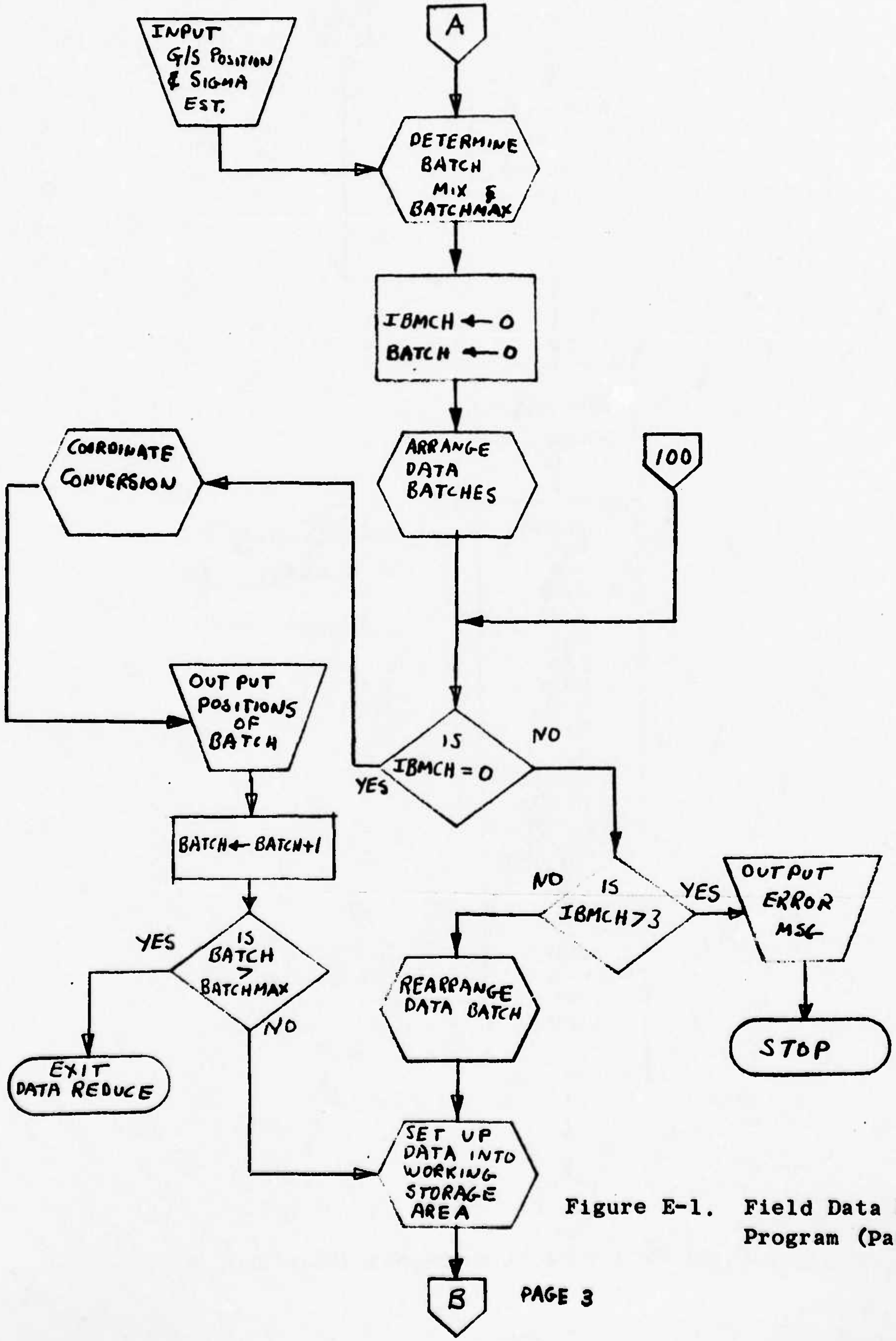

Figure E-1. Field Data Reduction Program (Page 2 of 8)

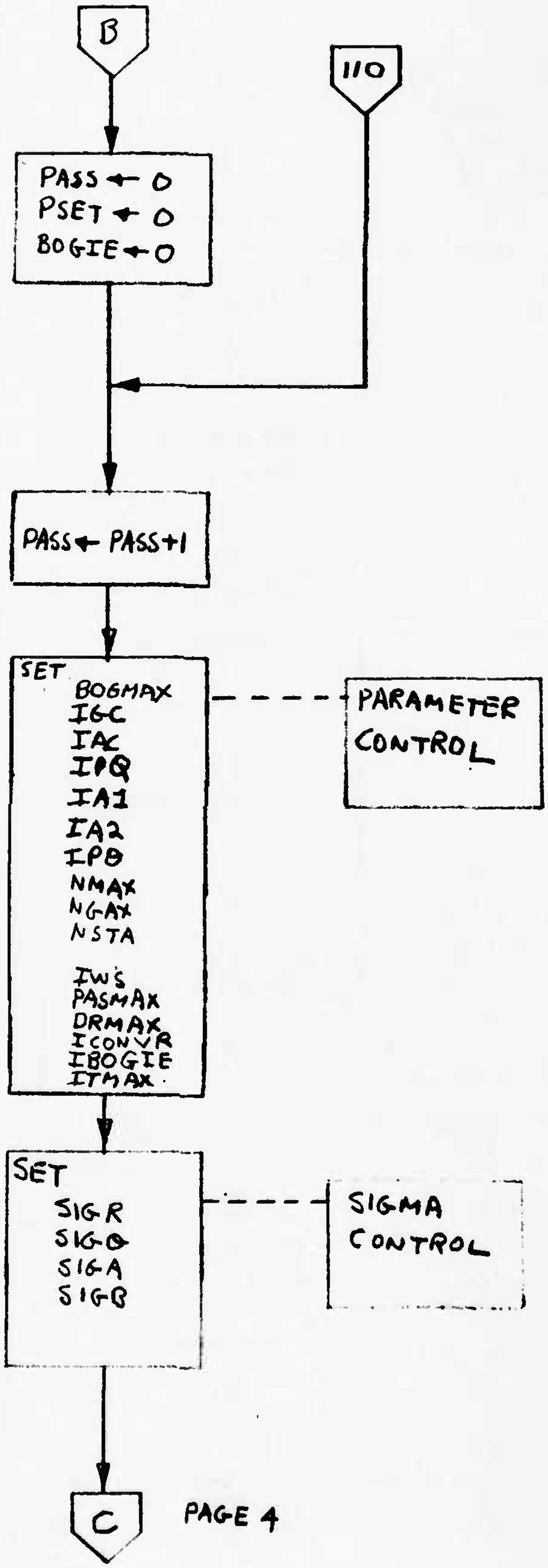

Figure E-1. Field Data Reduction Program (Page 3 of 8)

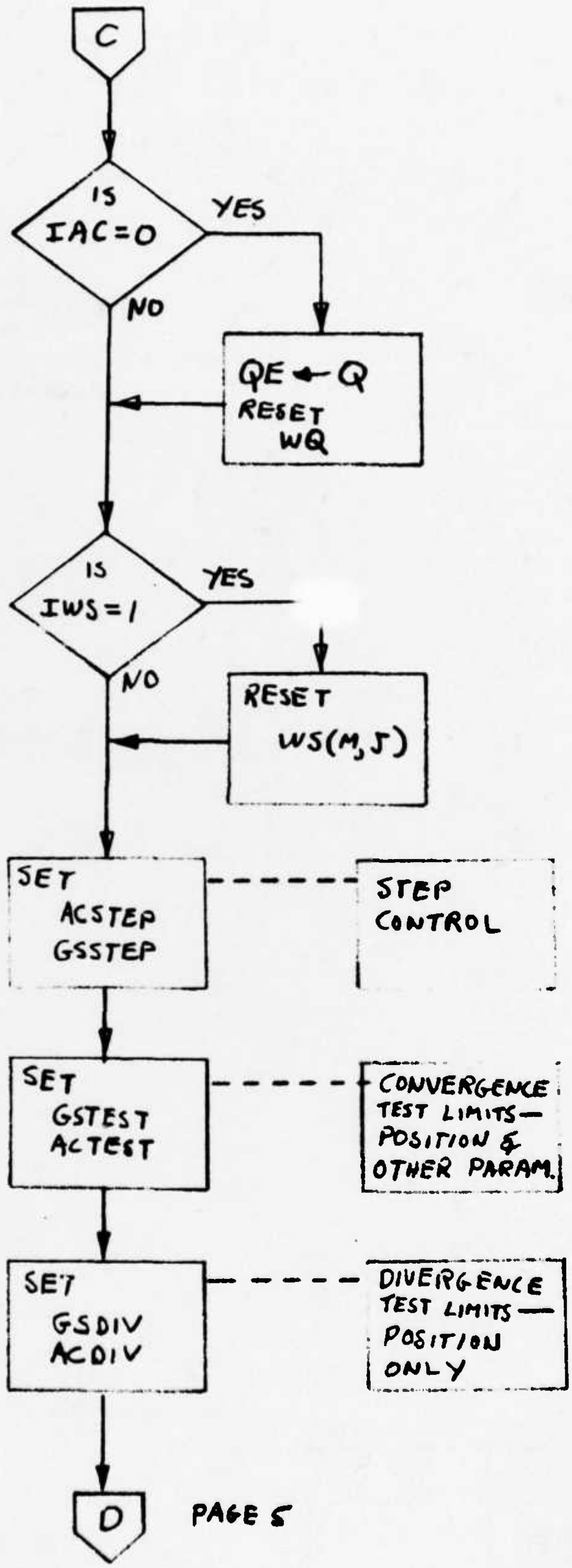

Figure E-1. Field Data Reduction Program (Page 4 of 8)

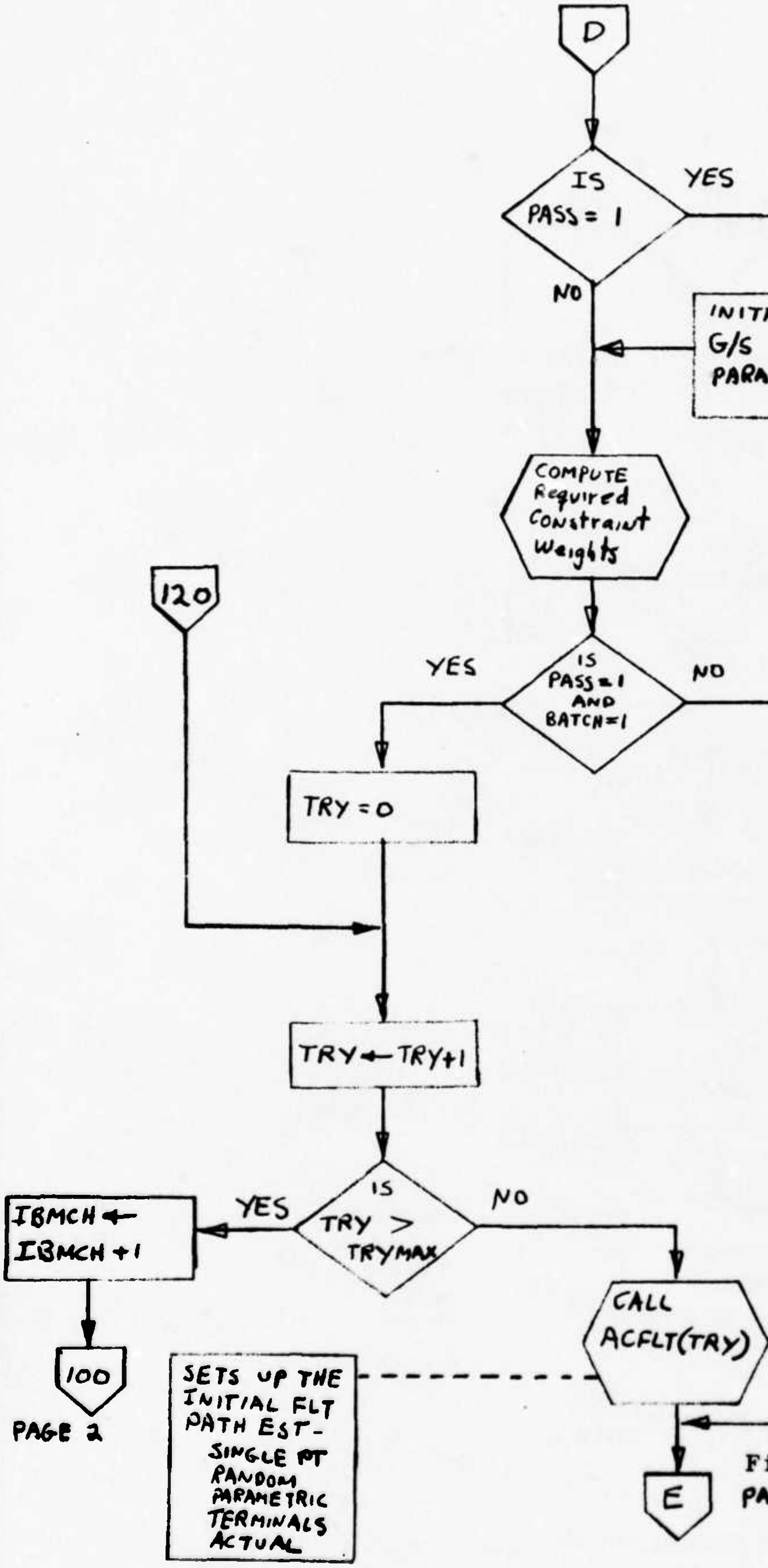

Figure E-1. Field Data Reduction Program (Page 5 of 8)

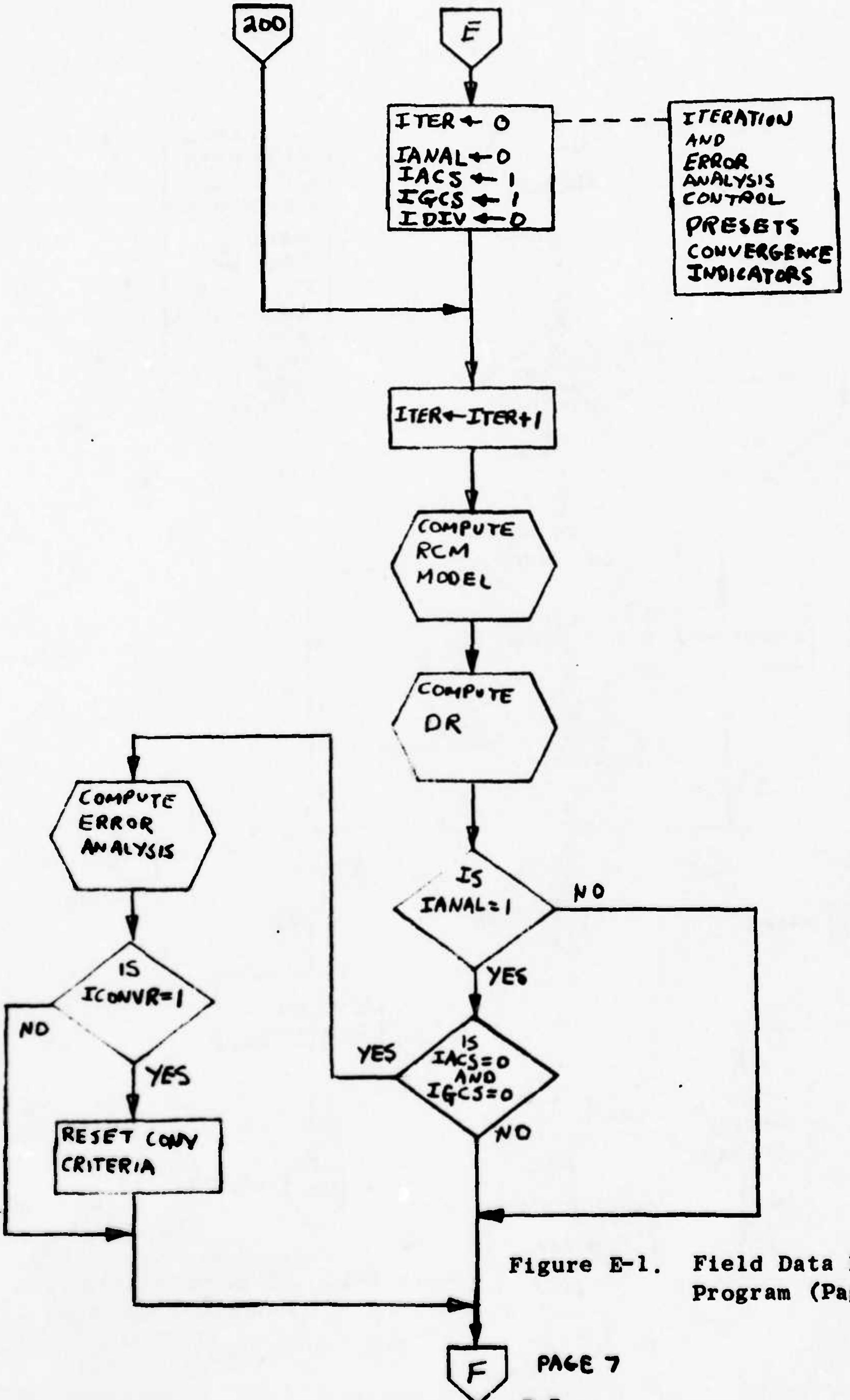

Figure E-1. Field Data Reduction Program (Page 6 of 8)

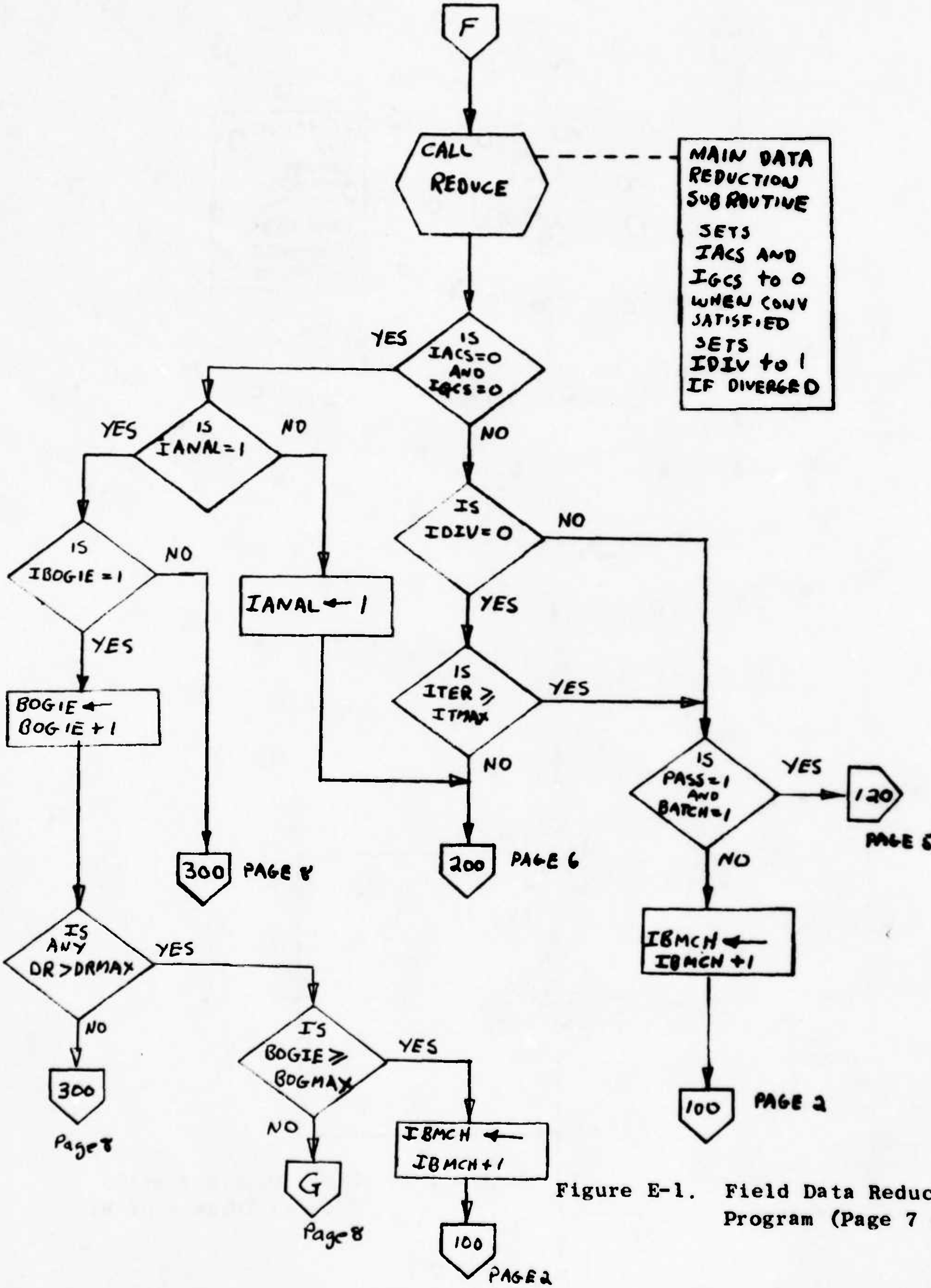

Figure E-1. Field Data Reduction Program (Page 7 of 8)

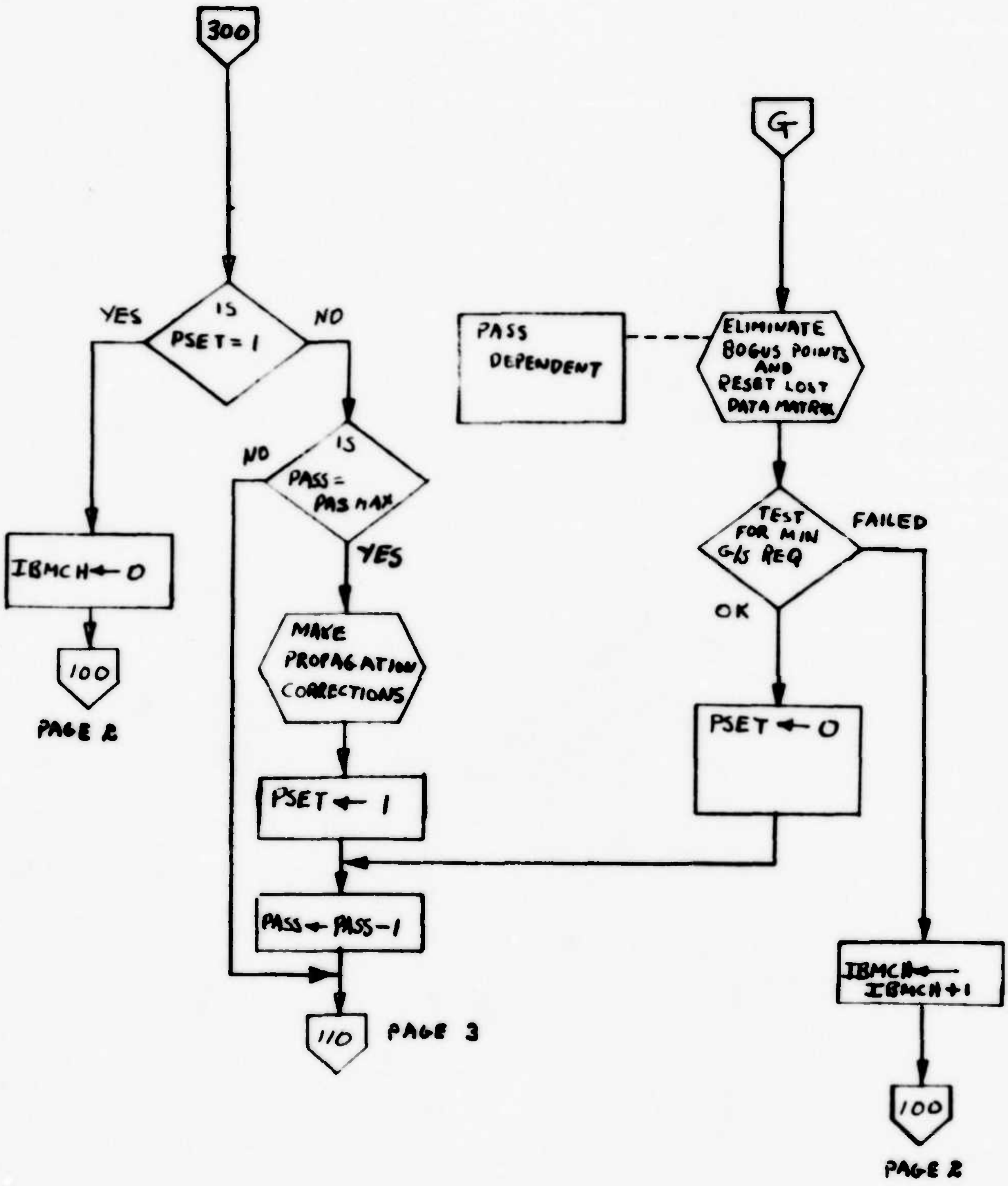

Figure E-1. Field Data Reduction Program (Page 8 of 8)"

APPENDIX F-1

LRPDS RELIABILITY MATHEMATICAL MODEL DEVELOPMENT

1. Assumptions

The following assumptions were applied in the development of the mathematical model.

a. The system is a series system as described by the LRPDS Reliability Block Diagram (See section 10-2 of this report.)

b. Operating times and duty cycles for each subsystem and unit used during a mission are as presented in Table F-1.2.

c. Times to failure follow an exponential distribution.

d. "Reliability" is defined as the probability that an item will operate without failure for the duration of the mission.

2. LRPDS Mission Time

The LRPDS consists of three subsystems, each of which operates for a different period of time during the mission. Furthermore, each subsystem is composed of units operating for different periods of time. Therefore, individual "mission" time has been developed for each subdivision of the system. These time elements are based on the "standard mission" as defined in paragraph 10.2.1 of this report, and are presented in the Reliability Block Diagram.

The operating times for each system subdivision were derived based on mission timing data developed during the LRPDS Mission Description study. The results of this study have been used to determine the approximate duration of each element of a "standard mission" (See table F-1.1.) These time elements are summed as appropriate to establish mission times for each unit of the system (See table F-1.2).

TABLE F-1.1

TIME ELEMENTS OF STANDARD MISSION

MISSION ELEMENT	TIME (Minutes)
Oscillator Warm-Up	
PS's and PCC/PS	240
A/C	120
Mission Initialization, etc.	
PCC	30
A/C	30
PS's	5
Initial A/C Position Run	7
Standby for P2 Command	5
Ranging Mission	46
Message Exchange	9
Data Processing & Reduction	15 *

* Estimate of computer time required after completion of mission.

TABLE F-1.2

EQUIPMENT OPERATING TIME

SUBSYSTEM/EQUIPMENT	DUTY CYCLE	OPERATING TIME (HOURS)
PCC Subsystem		
Master Oscillator	1.00	5.9
PCC/PS (All except XMTR)	1.00	1.6
PCC/PS Transmitter	.03	1.6
All other PCC Units	1.00	1.9
Reference Position Subsystem (A/C)		
Rubidium Frequency Standard	1.00	3.5
Transmitter	.75	1.6
All other A/C Units	1.00	1.6
Positioning Set Subsystem		
Master Oscillators	1.00	5.2
Transmitters	.02	1.2
All other PS Units	1.00	1.2

In addition, operating duty cycles were determined for those items (transmitter) that are operated intermittently. These are based on the approximate time required to transmit each of the various commands and messages associated with the standard mission.

3. Basic Reliability Model

The reliability of a system composed of a number of elements connected in series (i.e., a failure in anyone of the elements causes a system failure) is given by the expression:

$$R_{s(T)} = \prod_{i=1}^{N} R_{i(ti)} \qquad (1)$$

Where:

$R_{s(T)}$ = the reliability of the system for mission time T.

$R_{i(ti)}$ = the reliability of system element i for its mission.

time t_i $t_i \leq T$

N = the number of elements in the system

This basic model can be expanded by considering an individual element of the system. Assuming the exponential distribution,

$$R_{(t)} = \exp\left[-\lambda t\right] \qquad (2)$$

Where:

λ = the failure rate of the system element under the operational and environmental conditions encountered during time period t.

Expression (2) assumes that the environmental and operating conditions remain constant for the entire mission. In general, individual subsystems of the LRPDS can be assumed to operate in a constant environment for the duration of the mission. However, certain system elements, in particular transmitters, will be cycled on and off during the mission. Assuming the failure rate of an item during operation is different than during periods of non-operation in the same environment, expression (2) can be modified:

$$R_{(t)} = \exp\left\{-[\lambda_o(t\cdot(d/c)) + \lambda_{n-o}(t\cdot(1 - d/c))]\right\} \qquad (3)$$

Where:

d/c = the duty cycle of the time, where duty cycle is the ratio of operating time to total time.

λ_o = the operating failure rate

λ_{n-o} = the non-operating failure rate

Failure rates are normally determined under operating conditions and non-operating failure rates are not available in most cases. Therefore, expression (3) is not readily useable. However, a number of non-operating or storage life studies have indicated that operating failure rates are at least 10 times greater than non-operating failure rates in the same environment. Therefore, for the purposes of this

1. One such study is reported in RADC-TR-67-307, "Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability".

model, it will be assumed that $\lambda_{n-o} = .1\,\lambda_o$, in which case, expression (3) becomes:

$$R_{(t)} = \exp\left\{-[\lambda t \cdot (d/c) + .1\,\lambda t \cdot (1 - d/c)]\right\}$$

Where:

λ = the operating failure rate.

Rearranging this expression gives:

$$R_{(t)} = \exp\,[-\lambda t\,(.9\,(d/c) + .1)] \qquad (4)$$

Expression (4) is used as the basic elemental expression in the development of the LRPDS Reliability Model.

4. Detailed Model Development

The LRPDS Reliability Model is based on the reliability block diagram (Figures 10-1 through 10-7 of this report). The system is assumed to have the following configuration:

a. One Position Computing Central (Block number 1000 of the block diagram).
b. One Reference Position Set (Block #2000)
c. 27 Positioning Sets (Block #3000), only 5 of which include a Data Display Unit (Block #3300).

From expression (1), the system reliability is expressed as:

$$R_s(5.9) = R_{1000}(5.9) \cdot R_{2000}(3.5) \cdot R_{3000}(5.2) \qquad (5)$$

The 4-digit numbers refer to block numbers of the reliability

block diagram, and the numbers in parentheses are the mission times, in hours, for the respective subsystem.[2]

The expression $R_{3000(5.2)}$ referes to the entire PS subsystem consisting of 27 Positioning Sets. Each of the subsystems reliabilities is expressed as the product of the reliabilities of the individual units of the subsystem. Individual factors of these expressions are then factored into more elemental subdivisions until the subsystem reliability can be expressed as the product of a set of exponential expressions each having the form of expression(4). This development for the three subsystems is described in the following paragraphs.

4.1 Position Computing Central Reliability Model:

$$R_{1000} = R_{1100} \cdot R_{1200} \cdot R_{1300} \cdot R_{1400}$$

(Note, block 1500 represents GFE and is not being considered in this interim report. Therefore, R_{1800} and R_{1900} is set equal to 1 in this model.)

R_{1220} can be expanded according to Figure 10-3, giving:

$$R_{1220} = R_{1221} \cdot R_{1222} \cdot R_{1223} \cdot R_{1224}$$

The PCC model has now been factored into the lowest terms possible at the present state of system definition. Each factor is now expressed

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2. This subscribing method will be continued without further explanation in the remainder of this appendix.

in the exponential form by substituting appropriate time and duty cycle values from Figures 10-2 and 10-3 in expression (4):

$$R_{1221} = \exp\left[-\lambda_{1221}\,(1.6 \times 1)\right] = \exp(-1.6\,\lambda_{1221})$$

$$R_{1222} = \exp\left\{-\lambda_{1222}\,[1.6\,(.9 \times .03 + .1)]\right\} = \exp(-.2\,\lambda_{1222})$$

$$R_{1223} = \exp(-1.6\,\lambda_{1223})$$

$$R_{1220} = \exp(-5.9\,\lambda_{1220})$$

$$R_{1300} = \exp(-1.9\,\lambda_{1300})$$

$$R_{1400} = \exp(-1.9\,\lambda_{1400})$$

$$R_{1500} = \exp(-5.9\,\lambda_{1500})$$

$$R_{1230} = \exp(-5.9\,\lambda_{1230})$$

Substituting these values in the expression for R_{1000}, collecting terms and simplying:

$$R_{1000} = \exp\left|-\left|1.6\,(\lambda_{1221} + \lambda_{1223}) + .2\,\lambda_{1222} + 5.9\,(\lambda_{1220} + \lambda_{1224} + \lambda_{1500}) + 1.9\,(\lambda_{1300} + \lambda_{1400})\right|\right|$$

4.2 Reference Position Set Reliability Model:

$$R_{2000} = R_{2100} \cdot R_{2200} \cdot R_{2300} \cdot R_{2400}$$

R_{2200} can be expanded according to Figure 10-5.

$$R_{2200} = R_{2210} \cdot R_{2220} \cdot R_{2230} \cdot R_{2240}$$

$$R_{2210} = R_{2211} \cdot R_{2212}$$

Expressing each factor in the exponential form by substituting appropriate time and duty cycle values from Figures 10-4 and 10-5 in expression (4):

$$R_{2100} = \exp\left(-1.6\,\lambda_{2100}\right)$$

$$R_{2211} = \exp\left(-1.6\,\lambda_{2211}\right)$$

$$R_{2212} = \exp\left\{-\lambda_{2212}\left[1.6\ (.9 \times .75 + .1)\right]\right\} = \exp\left(-1.2\,\lambda_{2212}\right)$$

$$R_{2220} = \exp\left(-1.6\,\lambda_{2220}\right)$$

$$R_{2230} = \exp\left(-1.6\,\lambda_{2230}\right)$$

$$R_{2240} = \exp\left(1.6\,\lambda_{2240}\right)$$

$$R_{2250} = \exp\left(-1.6\,\lambda_{2250}\right)$$

$$R_{2300} = \exp\left(-3.5\,\lambda_{2300}\right)$$

$$R_{2400} = \exp\left(-1.6\,\lambda_{2400}\right)$$

Substituting these values in the expression for R_{2000}, collecting terms and simplifying:

$$R_{2000} = \exp\left\{-\left[1.6\ (\lambda_{2100} + \lambda_{2211} + \lambda_{2220} + \lambda_{2230} + \lambda_{2240} + \lambda_{2250} + \lambda_{2400}) + 1.2\,\lambda_{2212} + 3.5\,\lambda_{2300}\right]\right\}$$

4.3 Positioning Set Reliability Model

The Positioning Set subsystem includes 27 PS's, only 5 of which include DDU's. Therefore, the subsystem reliability model is expressed:

$$R_{3000} = (R_{3100} \cdot R_{3200} \cdot R_{3400})^{27} \cdot (R_{3300})^{5}$$

R_{3100} can be expanded according to Figure 10-7.

$$R_{3100} = R_{3110} \cdot R_{3120} \cdot R_{3130}$$

$$R_{3110} = R_{3111} \cdot R_{3112}$$

Expressing each factor in the exponential form by substituting appropriate time and duty cycle values from Figures 10-6 and 10-7. in expression (4):

$$R_{3111} = \exp\left(-1.2\,\lambda_{3111}\right)$$

$$R_{3112} = \exp\left\{-\lambda_{3112}\left[1.2\,(.9 \times .02 + .1)\right]\right\} = \exp\left(-.14\,\lambda_{3112}\right)$$

$$R_{3120} = \exp\left(-1.2\,\lambda_{3120}\right)$$

$$R_{3130} = \exp\left(-1.2\,\lambda_{3130}\right)$$

$$R_{3200} = \exp\left(-5.2\,\lambda_{3200}\right)$$

$$R_{3300} = \exp\left(-1.2\,\lambda_{3300}\right)$$

$R_{3400} = 1$ for this model because battery is not yet defined.

Substituting these values in the expression for R_{3000}, collecting terms, and simplifying:

$$R_{3000} = \left\{\exp\left[-1.2\,(\lambda_{3111} + \lambda_{3120} + \lambda_{3130}) - .14\lambda_{3112} - 5.2\,\lambda_{3200}\right]\right\}^{27} \cdot \left\{\exp\left[-1.2\,\lambda_{3300}\right]\right\}^{5}$$

5. <u>Relationship Between Elements of Reliability Model and Hardware Subdivisions</u>

The failure rate factors (λ_{xxxx}) represent failure rates of the largest subdivisions of major units of the respective equipment for

which the mission time and duty cycle would be consistent, and correspond to the various blocks of the reliability block diagram. In essentially all cases, these blocks can be further subdivided into modules; however, such subdivision is not necessary in most cases because the block failure rate is equal to the sum of the failure rates of the modules. However, in the case of the RTU's, modules making up the transmit circuitry operate at a lower duty cycle than modules making up the receive circuitry. Module or circuitry operating at the different duty cycles are listed below.

Receive Circuitry (Blocks 1111, 2211 and 3111)

- Power Converter
- RF/IF
- Synthesizer (Receive portion)
- Carrier IQ/VCO
- Code Detector
- CACU (70% of total module failure rate)
- Clock IQ/Phase Control
- RTU Cable Harness

Transmit Circuitry (Blocks 1112, 2212 and 3112)

- Power Amplifier/Modulator
- Synthesizer (Transmit Portion)
- CACU (30% of total module failure rate)

APPENDIX F-2

LRPDS RELIABILITY ALLOCATION

1. Allocation to Subsystems

The effective maximum allowable system failure rate is 26000 failures per million hours (26,000 f/10^6).[1] This failure rate is allocated to the three subsystems such that the sum of the failure rates of the individual subsystems is equal to the total system failure rate. Other factors considered in the allocation include the relative subsystem complexity and variation in mission time constraints.

Two basic relationships are used in performing the allocations. First, in a series system, the system reliability is the product of the subsystem reliabilities. Assuming an exponential distribution,

$$\exp(-\lambda_s T) = \prod_{i=1}^{N} \exp(-\lambda_i t_i) = \exp\left[-\sum_{i=1}^{N} \lambda_i t_i\right]$$

Where:

λ_s = the system failure rate

T = the system mission time (the maximum mission time for any subsystem)

λ_i = the failure rate for sybsystem i

t_i = the mission time for subsystem i

N = the number of subsystems

Taking the logarithm of this expression and rearranging gives:

$$\lambda_s = \sum_{i=1}^{N} \frac{\lambda_i t_i}{T} \qquad (1)$$

---

1. The failure rate of a series system is the reciprocal of the MTBF. Thus, the effective maximum allowable failure rate for the LRPDS = 1/38 hours = .026 failures per hour.

Furthermore, in a series system the system failure rate is the sum of the subsystem failure rates such that

$$\lambda_s = \sum_{i=1}^{N} \lambda_i \tag{2}$$

Both expressions (1) and (2) are used in performing the allocation.

The system and subsystem mission times being assumed for this report are as follows (see paragraph 2.1.2).

LRPDS System: $T = 5.9$ hours

PCC Subsystem: $t_{1000} = 5.9$ hours

RPS Subsystem: $t_{2000} = 3.5$ hours

PS Subsystem: $t_{3000} = 5.2$ hours

Substituting these values, and the system

(λ_s = .026 f/hour)

failure rate (λ_s = .025 f/hour) in expressions (1) and (2):

$$\frac{5.9\lambda_{1000}}{5.9} + \frac{3.5\lambda_{2000}}{5.9} + \frac{5.2\lambda_{3000}}{5.9} = .026 \text{ f/hour}$$

$$\lambda_{1000} + .59\lambda_{2000} + .88\lambda_{3000} = .026 \tag{3}$$

$$\lambda_{1000} + \lambda_{2000} + \lambda_{3000} = .026 \tag{4}$$

These two expressions cannot be solved simultaneously because (1) there are 3 unknowns, and (2) direct solution would provide at least one negative λ value. Therefore, λ values are determined that will satisfy expression (3) and that reflect the relative subsystem

complexity. Different environmental "K-factors" are also considered. Final allocations are determined by adjusting the λ values to satisfy expression (4) while maintaining the relative weights that were established using expression (3).

The following observations are made regarding the complexity and other factors relating to the relative failure rates of the three subsystems.

a. Comparison between RPS and PS: The RPS isnot more than 10% more complex than individual PS. Therefore, an individual PS failure rate (λ_{3000}) would be approximately $.9\lambda_{2000}$ in the same environment. However, the PS subsystem consists of 27 individual PS's. Thus, the PS subsystem is estimated to be 27 x .9 = 24.3 times as complex as the RPS subsystem. Also, even though the two subsystems operate in different environments, the environmental "K-factors" are the same for both subsystems.[2.] Based on these observations, the RPS and PS subsystem failure rates are allocated such that:

$$\lambda_{3000} = 24.3\lambda_{2000} \qquad (5)$$

b. Comparison between RPS and PCC: Based on the number and types of blocks in the PCC block diagram (Figure 10-2) as compared to the RPS block diagram (Figure 10-4), it is apparent that the PCC is at least 5 times as complex as the RPS. However, the PCC operates

2. See section 10.4 for a discussion of reliability "K-factors"

in a fixed, ground environment while the RPS operates in an airborne environment. The average ratio between fixed ground and airborne "K-factors" in *MIL-HDBK-217A* is approximately .16:1. Based on these observations, the system failure rates will be allocated such that:

$$\lambda_{1000} = (5 \times .16)\lambda_{2000}$$

$$\lambda_{1000} = .8\lambda_{2000} \tag{6}$$

Substituting (5) and (6) in (3):

$$.8\lambda_{2000} + .59\lambda_{2000} + 24.3(.88)\lambda_{2000} = .026$$

$$\lambda_{2000} = \frac{.026}{22.9} = .0011 \text{ f/hour} \tag{7}$$

Substituting (7) in (5) and (6):

$$\lambda_{3000} = 24.3\ (.0011) = .0267 \text{ f/hour} \tag{8}$$

$$\lambda_{1000} = .8\ (.0011) = .0009 \text{ f/hour} \tag{9}$$

These values are adjusted such that expression (4) is satisfied:

$$\lambda_{1000} + \lambda_{2000} + \lambda_{3000} = .0009 + .0011 + .0267 = .0287$$

But, from (4):

$$\lambda_{1000} + \lambda_{2000} + \lambda_{3000} = .026$$

Therefore, the λ values are multiplied by $\frac{.026}{.0287} = .91$ and adjusted slightly to provide the following allocations.

PCC: λ_{1000} = .0008 f/hour = 800 f/10^6

RPS: λ_{2000} = .0009 f/hour = 900 f/10^6

PS: λ_{3000} = .0243 f/hour = 24,300 f/10^6

Total System λ = 26,000 f/10^6

2. Positioning Set Subsystem Allocation

The PS subsystem failure rate (λ_{3000}) is allocated to the lower subdivision first because the Positioning Unit is a fundamental element of the system, and similar units are used in the RPS and PCC subsystems.

The PS subsystem consists of 27 Positioning Sets, 5 of which include a Data Display Unit (DDU). Thus, the subsystem failure rate is allocated to 27 positioning units (block 3100 of Figure 10-6), 27 Crystal Oscillators (block 3200) and 5 DDU's (block 3300). The battery (block 3400) is ignored in the initial allocation because (a) the specific type of battery to be used is in doubt at this time and (b) batteries are highly reliable devices (typical failure rates are in the order of 1 f/10^6 or less) and therefore, do not contribute significantly to the system failure rate. In the final allocation, a failure rate of 1 f/10^6 is allocated to the battery.

The PS subsystem reliability is expressed in the model (paragraph 10.2.3c) as:

$$R_{3300} = (R_{3100} \cdot R_{3200})^{27} (R_{3300})^5 \tag{10}$$

Where:

$$R_{3100} = \exp \left| -(1.2\ \lambda_{3100}) \right| \tag{11}$$

$$R_{3200} = \exp\left[-(5.2\,\lambda_{3200})\right] \quad (12)$$

$$R_{3300} = \exp\left[- (1.2\,\lambda_{3300})\right] \quad (13)$$

Also, the reliability block diagram (Figure 10-1) gives T_{3000} = 5.2 hours, and the allocated failure rate for this subsystem is λ_{3000} = .0243 f/hour.

Therefore:

$$R_{3000} = \exp\left[- (.0243 \times 5.2)\right] \quad (14)$$

Substituting (11), (12), (13) and (14) in (10):

$$\exp\left[-(.0243 \times 5.2\right] = \exp\left[-(27 \times 1.2)\,\lambda_{3100} + (27 \times 5.2)\,\lambda_{3200} + (5 \times 1.2)\,\lambda_{3300})\right]$$

Taking the logarithm and rearranging:

$$19.8\,\lambda_{3100} + 27\,\lambda_{3200} + 1.15\,\lambda_{3300} = .0243 \quad (15)$$

Also, this is a series system and,

$$27\,\lambda_{3100} + 27\,\lambda_{3200} + 5\,\lambda_{3300} = .0243 \quad (16)$$

The following observations are made concerning relative complexities.

a. Comparison of Crystal Oscillator and Positioning Unit. The crystal oscillator consists of approximately 150 parts compared to approximately 2500 parts in the Positioning Unit. Therefore, it is assumed that:

$$\lambda_{3200} = \frac{150}{2500}\,\lambda_{3100} = .06\,\lambda_{3100} \quad (17)$$

b. Comparison of DDU and Positioning Unit: The DDU contains approximately 140 parts, 20 of which are LED indicators. These devices are roughly equal to 14 diodes and one IC, or the equivalent of 16 parts. Therefore, it is assumed that the DDU is approximately 500/2500 as complex as the Positioning Unit, and:

$$\lambda_{3300} = .2\lambda_{3100} \qquad (18)$$

Substituting (17) and (18) in (15):

$$19.8\lambda_{3100} + 27\ (.06\lambda_{3100}) + 1.15\ (.2\ \lambda_{3100}) = .0243$$

$$\lambda_{3100} = \frac{.0243}{21.65} = .00113$$

Substituting this value in (17) and (18):

$$\lambda_{3200} = .06 \times .00113 = .00007$$

$$\lambda_{3300} = .2 \times .00113 = .000226$$

This is checked in (15) which states:

$$27\lambda_{3100} + 27\lambda_{3200} + 5\lambda_{3300} = .0243$$

But, substituting the calculated λ values:

$$27 \times .00113 + 27 \times .00007 + 5 \times .000225 = .0335$$

Therefore, the λ values are adjusted by a factor of $\frac{.0243}{.0335} = .73$ giving:

Positioning Unit: $\lambda_{3100} = .820\ f/10^6$

Crystal Oscillator: $\lambda_{3200} = 50\ f/10^6$

DDU: $\lambda_{3300} = 169\ f/10^6$

Battery: $\lambda_{3400} = 1\ f/10^6$

2.1 Positioning Unit Allocation

The positioning unit failure rate, $\lambda_{3100} = 820\ f/10^6$ is allocated to the RTU, DPU and control panel in proportion to the estimated failure rates as determined during preliminary predictions. This procedure is used in lieu of a complexity or part count weighting procedure because the analog circuitry of the RTU is expected to have considerable higher failure rate to part count ratio than the digital circuitry of the DPU.

A preliminary prediction that was available before this allocation was performed indicating approximate failure rates as follows:[3]

Unit	Failure Rate	Percentage
RTU	680	.60
DPU	210	.20
Cont. Panel	220	.20
Total	1110	1.00

3. These are preliminary and are used for weighting quantities only. See section 10.4 for actual prediction results.

Using these percentage as weighting factors provides the following allocation of Positioning unit failure rates:

RTU: $\lambda_{3110} = 820 \times .60 = 490\ f/10^6$

DPU: $\lambda_{3120} = 820 \times .20 = 165\ f/10^6$

Cont. Panel: $\lambda_{3130} = 820 \times .20 = 165\ f/10^6$

2.2.1 Allocation to Modules of PS Positioning Unit:

The RTU and DPU allocations are allocated to modules using approximate failure rates obtained from the preliminary predictions. These allocations are listed in Table F-2.1.

3. Reference Position Set Allocation

The Reference Position Set consists of a Control and Monitor Unit (block 2100 of Figure 10-4), a Reference Position Unit (block 2200), a Rubidium Frequency Standard (block 2300) and an Altimeter (block 2400). The subsystem reliability can be expressed according to the model (paragraph 2.1.5b) as:

$$R_{2000} = R_{2100} \cdot R_{2200} \cdot R_{2300} \cdot R_{2400} \qquad (19)$$

Where:

$$R_{2100} = \exp\ (-1.6\lambda_{2100}) \qquad (20)$$

$$R_{2200} = \exp\ (-1.6\lambda_{2200}) \qquad (21)$$

$$R_{2300} = \exp\ (-3.5\lambda_{2300}) \qquad (22)$$

$$R_{2400} = \exp\ (-1.5\ \lambda_{2400})$$

Also, the reliability block diagram (Figure 10-1) gives $T_{2000} = 3.5$ hours, and the allocated failure rate for this subsystem is $\lambda_{2000} = 900 \text{ f}/10^6 = .0009$ f/hour

Therefore:

$$R_{2000} = \exp\left[-(.0009 \times 3.5)\right] \qquad (23)$$

Substituting (20), (21), (22), and (23) in (19):

$$\exp\left[-(.0009 \times 3.5)\right] = \exp\left[-(1.6\lambda_{2100} + 1.6\lambda_{2200} + 1.6\lambda_{2400} + 3.5\lambda_{2300})\right]$$

Taking the logarithm and rearranging:

$$.46\,(\lambda_{2100} + \lambda_{2200} + \lambda_{2400}) + \lambda_{2300} = .0009 \qquad (24)$$

Also, the RPS is a series system, and

$$\lambda_{2100} + \lambda_{2200} + \lambda_{2300} + \lambda_{2400} = .0009 \qquad (25)$$

The following observations are made regarding therelative complexity of RPS units.

a. The Reference Position Unit is similar to, but somewhat more complex than the PS Positioning Unit. The unit contains more digital circuitry, a more complex memory unit, and a separate memory power supply. However, the unit does not contain the 33 data switches such as are included on the PS control panel. Therefore, the Reference Position Unit should be only slightly less reliable than the PS Positioning Unit. The preliminary allocation for the positioning equipment is:

$$\lambda_{2200} = .00150 \text{ f/hour} \qquad (26)$$

b. The CMU is a relatively simple control box containing switches and indicators for operating the RPS. The unit contains approximately 7 switches, 11 Bite indicators, and 2 electrical connectors. Failure rate values for this type of component is usually in the order of 1 to 5 $f/10^6$, so that the total CMU failure rate should be between 20 and 100 $f/10^6$. Therefore, the preliminary value for the CMU failure rate allocation is:

$$\lambda_{2100} = .0005 \text{ f/hour} \qquad (27)$$

c. The altimeter is a relatively simple device consisting of a transducer and simple A-D converter. The failure rate of this device should be significantly less than that of the CMU. Therefore, the preliminary value assigned to this unit is:

$$\lambda_{2400} = .000005 \text{ f/hour} \qquad (28)$$

Substituting (26), (27) and (28) in (24):

$$.46\ (.00150 + .00005 + .000005) + \lambda_{2300} = .0009$$

$$\lambda_{2300} = .0009 - .0007 = .00025 \text{ f/hour} \qquad (29)$$

The sum of the values of (26), (27), (28) and (29) is

$$.00150 + .00005 + .000005 + .0002 = .001755$$

But, from (25), this sum should be .0009.

Therefore, the preliminary λ values are adjusted by a factor of

$\frac{.0009}{.0018} = .50$, and the allocated values are:

CMU: $\lambda_{2100} = 23\ f/10^6$

Ref Pos Unit: $\lambda_{2200} = 750\ f/10^6$

Rubidum std: $\lambda_{2300} = 125\ f/10^6$

Altimeter: $\lambda_{2400} = 2\ f/10^6$

3.1 Reference Position Unit:

The Reference Position Unit (block 2200) consists of five units as shown in Figure 2-5. The RTU is identical to the PS RTU and is allocated the same failure rate, such that:

$$\lambda_{2210} = .00049 \text{ f/hour}$$

The DPU (block 2220) is similar to the PS DPU in construction. The memory, which is included as part of the PS DPU, is a separate unit in the RPS. However, there are approximately twice as many digital modules, each of which is similar in complexity to the PS DPU modules. Therefore, the preliminary allocation for the RPS DPU is approximately the same as for the PS DPU, or:

$$\lambda_{2220} = .00015 \text{ f/hour}$$

The remaining failure rate of .00019 is allocated to the memory (block 2230), memory power supply (block 2240), and the Antenna Filter (block 2250) in relation to the estimated relative complexity. The preliminary allocation for the positioning equipment is:

RTU:	λ_{2210}	$= 490 \text{ f}/10^6$
DPU:	λ_{2220}	$= 150 \text{ f}/10^6$
Memory:	λ_{2230}	$= 75 \text{ f}/10^6$
Memory P.S.:	λ_{2240}	$= 33 \text{ f}/10^6$
Antenna Filter:	λ_{2250}	$= 2 \text{ f}/10^6$

3.1.1 Allocation to Modules of the Reference Position Unit

Failure rates of the RTU are allocated to modules in accordance with the allocations to comparable modules of the PS RTU (block 3110), and are summarized in Table B-1. (Allocations to low subdivisions of the other units will be performed at a later date.)

4. Position Computing Central Allocation

Due to the preliminary status of the PCC subsystem definition, the allocation will be performed for the PCC/PS (block 1100) only. The remaining portion of the subsystem failure rate will be allocated to the other units when the subsystem is sufficiently defined.

The PCC/PS is essentially the same as the PS, (including positioning unit and master oscillator). However, the sheltered ground environment, and the environmental "K-factor" is less by a factor of approximately .16:1. Also, the PS control panel is not used.

Therefore, the allocation to the PCC/PS is .16 times the PS, or:

$$\lambda_{1220} = .16\,(\lambda_{3100} + \lambda_{3200}) = .16\,(820 + 50 - 165)$$

$$\lambda_{1220} = 115\ f/10^6$$

This is allocated to the various units and modules of the PCC/PS by multiplying the respective PS module failure rates by .16. The results of this allocation is presented in Table F-2.1.

TABLE F-2.1 FAILURE RATE ALLOCATION SUMMARY

SYSTEM BREAKDOWN	BLOCK NUMBER	FAILURE RATE ALLOCATIONS (f/10⁶ HRS)				
		SYSTEM	SUBSYS	MAJOR UNIT	UNIT	MODULE
AN/USQ-56(V)	0000	26,000				
AN/TSQ-100	1000		800			
PCC/PS	1220			115		
RTU					80	
POWER CONV.	—					8
RF/IF	—					4
PA/MODULATOR	—					25
FREQ. SYNTH(T&R)	—					22
CARR IQ/VCO	—					9
CODE DETECTOR	—					3
CACU	—					4
CLOCK IQ/PH.CONT	—					5
DPU	1223				27	
RCDU	—					4
POWER SUPPLY	—					7
WORD CONTROL	—					2
MESSAGE OUTPUT	—					2
DATA ASSEMBLER	—					2
COMMAND DECODER	—					2
MEMORY	—					3
CABLE HARNESS	—					4
CRYSTAL FREQ. STD.	1224				8	
ALL OTHER PCC UNITS				685		
AN/ASQ-148	2000		900			
CONT.-MONITOR UNIT	2100			23		
REFERENCE POSITION UNIT	2200			750		
RTU	2210				490	
POWER CONVERT.	—					42
RF/IF	—					18
PA/MODULATOR	—					142
FREQ.SYNTH.(T&R)	—					127
CARR IQ/VCO	—					52
CODE DETECTOR	—					15
CACU	—					19
CLOCK IQ/PH.CONT	—					64
CABLE HARNESS	-					11
DPU	2270				150	
MEMORY	2230				75	
MEMORY P.S.	2240				33	
ANTENNA FILTER	2250				2	
RUBIDIUM FREQ STD	2300			125		
ALTIMETER	2400			2		

TABLE F-2.1 FAILURE RATE ALLOCATION SUMMARY (CONTINUED)

SYSTEM BREAKDOWN	BLOCK NUMBER	FAILURE RATE ALLOCATION ($f/10^6$ HRS)				
		SYSTEM	SUBSYS	MAJOR UNIT	UNIT	MODULE
AN/PSQ-101	3000					
FULL SUBSYSTEM (27 PS's AND 5 DDU'S)			24,300			
POSITIONING UNIT	3100			820		
RTU	3110				490	
POWER CONV	–					42
RF/IF	–					18
PA/MODULATOR	–					142
FREQ. SYNTH (T&R)	–					127
CARR IQ/VCO	–					52
CODE DETECTOR	–					15
CACU	–					19
CLOCK IQ/PH. CONT	–					64
CABLE HARNESS	–					11
DPU	3120				165	
RCDU	–					21
POWER SUPPLY	–					44
WORD CONTROL	–					13
MSG OUTPUT	–					13
DATA ASSEMBLER	–					13
CMD DECODER	–					13
MEMORY	–					21
CABLE HARNESS	–					27
CONTROL PANEL	3130				165	
CRYSTAL FREQ STD	3200			50		
DATA DISPLAY UNIT	3300			169		
BATTERY	3400			1		

APPENDIX F-3
RELIABILITY CALCULATIONS

1. RELIABILITY MODEL SOLUTIONS

"Standard Mission" reliability values are calculated below for allocated failure reates, and for worst case, typical operation, and reliability test prediction failure rates.

1.1 PCC MISSION RELIABILITY

The PCC Reliability for the standard mission is calculated using the allocated failure rates (See Table F-2.1).

The reliability mathematical model for the PCC subsystem is:

$$R_{1000} = \exp\left\{-[1.6(\lambda_{1221}+\lambda_{1223}) + .2(\lambda_{1222}) + 5.9(\lambda_{1224} + \lambda_{1220} + \lambda_{1500} + 1.9(\lambda_{1300}+\lambda_{1400})]\right\}$$

λ values are determined as follows from allocated failure rates, and considering the hardware items included in each block of the reliability block diagram.

Block	Item	Failure Rate ($F/10^6$)
1221	RTU Receive Circuitry	
	Power Converter	8
	RF/IF	4
	Receive Synth	11
	Carr. IQ/VCO	9
	Code Detector	3
	70% of CACU	3
	Clock IQ/PH. Cont	5
	Total λ_{1111}	43
1223	DPU	27

Block	Item	Failure Rate ($f/10^6$)
1222	RTU Transmit Circuitry	
	PA/Modulator	25
	Trans. Synth	11
	30% of CACU	1
	Total λ_{1112}	37
1224	Crystal Freq. Std.	8
	All other PCC Units	685

Substituting these values in the model:

$$R_{1000} = \exp\left\{-[\,1.6\,(.00007) + .2\,(.000037) + 5.9\,(.000008) + 1.9\,(.000685)]\right\}$$

$$= \exp\,(-.00147) = .9985$$

1.2 RPS MISSION RELIABILITY

The RPS reliability for the standard mission is calculated using allocated failure rates from Table F-2.1, and worst case, typical operation, and reliability test failure rates from the prediction data sheets in Appendix F-4. (See Table F-3.1).

The reliability mathematical model for the RPS subsystem is:

$$R_{2000} = \exp\left\{-[1.6\,(\lambda_{2100} + \lambda_{2212} + \lambda_{2220} + \lambda_{2230} + \lambda_{2240}\ \lambda_{2250}) + 1.2\lambda_{2212} + 3.5\lambda_{2300}]\right\}$$

Substituting these data in the reliability model gives allocated and predicted mission reliability as follows:

a. Allocated Reliability:

$$R_{2000} = \exp\left\{-\left[\, 1.6\ (.000025 + .000291 + .000150 + .000110 + .000060 + .000020) + 1.2\ (.000219) + 3.5\ (.000025)\right]\right\}$$

$$R_{2000} = \exp\ (.0014) = .9986$$

b. Worst Case Prediction

$$R_{2000} = \exp\left\{-\left[\, 1.6\ (.000061 + .000545 + .000295 + .000250 + .000092 + .000001) + 1.2\ (.000402) + 3.5\ (.001321)\right]\right\}$$

$$R_{2000} = \exp\ (-.0071) = .9929$$

c. Typical Operation Prediction

$$R_{2000} = \exp\left\{-\left[\, 1.6\ (.000024 + .000275 + .000115 + .000098 + .000056 + .0000002) + 1.2\ (.000202) + 3.5\ (.000486)\right]\right\}$$

$$R_{2000} = \exp\ (-.0029) = .9971$$

d. Reliability Test Condition Prediction

$$R_{2000} = \left\{-\left[\, 1.6\ (.000006 + .000124 + .000064 + .000092 + .000014 + .0000001) + 1.2\ (.000075) + 3.5\ (.000085)\right]\right\}$$

$$R_{2000} = \exp\ (-.00087) = .99913$$

TABLE F-3.1

RPS FAILURE RATE VALUES

BLOCK	ITEM	ALLOCATION	WORST CASE	TYPICAL	R TEST
			λ (f/10^6)		
2100	Control & Monitor Unit	25	60.75	24.14	5.72
2211	RTU Receive Circuitry				
	Power Converter	44	79.51	41.37	9.82
	RF/IF	19	36.01	18.19	7.63
	Receive Synth	66	123.09	65.98	23.38
	Carrier IQ/VCO	54	98.61	52.46	25.78
	Code Detector	16	30.55	13.09	13.67
	70% of CACU	14	29.24	10.18	7.28
	Clock IQ/ph cont.	66	125.43	63.50	31.80
	Cable Harness	12	22.26	10.22	4.35
	Total λ_{2211}	291	544.69	274.99	123.71
2220	DPU	150	295.44	114.99	63.98
2230	Memory	110	250.43	98.37	91.58
2240	Memory Power Supply	60	92.11	55.68	14.18
2250	Antenna Filter	20	1.24	.18	.11
2212	RTU Transmit Circuitry				
	PA/Modulator	147	267.90	132.86	48.62
	Transmitter Synth	66	121.58	64.47	23.06
	30% of CACU	6	12.53	4.37	3.12
	Total λ_{2212}	219	402.01	201.70	74.80
2300	Rubidium Freq. Standard	25	1321.15	486.23	85.15

TABLE F-3.2

PS FAILURE RATE VALUES

BLOCK	ITEM	ALLOCATION	λ (f/10^6) WORST CASE	TYPICAL	R TEST
3111	RTU Receive Circuitry				
	Power Converter	42	81.1	41.4	9.8
	RF/IF	18	36.0	18.2	7.6
	Receiver Synth	64	121.6	55.5	23.4
	Carrier IQ/VCO	52	98.6	52.5	25.8
	Code Detector	15	30.6	13.1	13.7
	70% of CACU	13	26.3	10.2	7.2
	Clock IQ/Ph. cont	64	121.5	63.5	31.8
	Cable Harness	11	22.2	10.2	4.4
	Total λ_{3111}	279	537.9	264.6	123.8
3120	DPU	165	339.1	132.3	75.3
3130	Control Panel	165	257.1	108.3	41.1
3112	RTU Transmit Circuitry				
	PA/Modulator	142	267.9	132.9	48.6
	Transmitter Synth	63	121.6	64.5	23.1
	30% of CACU	6	11.3	4.4	3.1
	Total λ_{3112}	211	400.8	201.8	74.8
3200	Crystal Oscillator	50	374.9	73.7	26.7
3300	Data Display Unit	170	165.1	96.6	48.4

1.3 PS SUBSYSTEM MISSION RELIABILITY

The PS subsystem reliability is calculated using allocated failure rates from Table F-2.1 and worst case, typical operation, and reliability test failure rate data from Appendix F-4. (See Table F-3.2). The reliability mathematical model for the PS subsystem is:

$$R_{3000} = (R_{3100} \cdot R_{3200})^{27} (R_{3300})^{5}$$

$$R_{3100} = \exp\left\{-[1.2 (\lambda_{3111} + \lambda_{3120} + \lambda_{3130}) + .14(\lambda_{3112})]\right\}$$

$$R_{3200} = \exp\left\{-[5.2 (\lambda_{3200})]\right\}$$

$$R_{3300} = \exp\left\{-[1.2 (\lambda_{3300})]\right\}$$

The values obtained from Table F-2.1 and Appendix F-4 are listed in Table F-3.2. Substituting these data in the reliability model gives allocated and predicted mission reliability as follows:

a. Allocated Reliability:

$$R_{3100} = \exp\left\{-[1.2 (.000279 + .000165 + .000165) + .14 (.000211)]\right\}$$

$$R_{3100} = \exp(-.00076) = .99924$$

$$R_{3200} = \exp\left\{-[5.2 (.000050)]\right\} = \exp(-.00026) = .99974$$

$$R_{3300} = \exp\left\{-[1.2 (.00017)]\right\} = \exp(-.000204) = .9998$$

$$R_{3000} = [(.9992)(.9997)]^{27} (.9998)^{5}$$

$$R_{3000} = (.9989)^{27} (.9998)^{5} = .9696$$

b. Worst Case Prediction

$$R_{3100} = \exp\left\{-\left[1.2\,(.000538 + .000339 + .000257) + .14\,(.000401)\right]\right\}$$

$$R_{3100} = \exp(-.00142) = .9986$$

$$R_{3200} = \exp\left\{-\left[5.2\,(.000374)\right]\right\} = \exp(-.00194) = .9981$$

$$R_{3300} = \exp\left\{-\left[1.2\,(.000165)\right]\right\} = \exp(-.000198) = .9998$$

$$R_{3000} = \left[(.9986)\,(.9981)\right]^{27}(.9998)^{5} = .9126$$

c. Typical Operation Prediction

$$R_{3100} = \exp\left\{-\left[1.2\,(.000265 + .000132 + .000108) + .14\,(.000202)\right]\right\}$$

$$R_{3100} = \exp(-.00063) = .9994$$

$$R_{3200} = \exp\left\{-\left[5.2\,(.000074)\right]\right\} = \exp(-.00039) = .9996$$

$$R_{3300} = \exp\left\{-\left[1.2\,(.000096)\right]\right\} = \exp(.000115) = .9999$$

$$R_{3000} = \left[(.9994)\,(.9996)\right]^{27}(.9999)^{5} = .9722$$

d. Reliability Test Condition Prediction

$$R_{3100} = \exp\left\{-\left[1.2(.000124 + .000075 + .000041) + .14\,(.000074)\right]\right\}$$

$$R_{3100} = \exp(-.000308) = .9997$$

$$R_{3200} = \exp\left\{-\left[5.2\,(.000027)\right]\right\} = \exp(-.00016) = .9998$$

$$R_{3300} = \exp\left\{-\left[1.2\,(.000048)\right]\right\} = \exp(-.000057) = .99995$$

$$R_{3000} = \left[(.9997)\,(.9998)\right]^{27}(.99995)^{5} = .9850$$

1.4 RELIABILITY UNDER TEST CONDITIONS

The ability of the system to pass the reliability test can be assessed by extrapolating the predicted reliability for a full system to provide an estimate of the MTBF for a reduced system under reliability test conditions. The reliability test will probably be performed on a system consisting of the following:

1 Position Computing Control

1 Reference Position Set

6 Positioning Sets

3 DDU's

The predicted reliabilities for test conditions are:

PCC: $R_{1000} = .9985$

RPS: $R_{2000} = .9991$

PS (one): $R_{3100} = .9997$

$R_{3200} = .9998$

$R_{3300} = .9997$

The estimated reliability for the reduced system is:

$$R_s = (.9985)\ (.9991)\ \left[(.9997)\ (.9998)\right]^6\ (.9997)^3 = .9928$$

Assuming a 2-hour mission:

$$.9928 = \exp\left[\,-2\,\lambda\right]$$

$$2\lambda = .0072,$$

$$\lambda = .0036 \text{ f/hour}$$

$$\text{MTBF} = \frac{1}{\lambda} = 280 \text{ hours}$$

APPENDIX F-4

RELIABILITY PREDICTION DATA SHEETS

4.1 AN/PSQ-101 WORST CASE

4.2 AN/PSQ-101 TYPICAL OPERATION

4.3 AN/PSQ-101 RELIABILITY TEST CONDITIONS

4.4 AN/ASQ-148 WORST CASE

4.5 AN/ASQ-148 TYPICAL OPERATION

4.6 AN/ASQ-148 RELIABILITY TEST CONDITIONS

APPENDIX F-4.1

WORST CASE

RELIABILITY PREDICTION DATA SHEETS

POSITIONING SET AN/PSQ-101

ENVIRONMENT: VEHICLE MOUNTED GROUND

TEMPERATURE: +71°C

STRESS LEVELS: DERATING LIMITS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER CONVERTER   MODEL R/T UNIT

DATE APR 12, '71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	3.0	60	5.00	.00962	.14423	217A	
CAPACITOR, SLD TANT, CSR	7.0	50	1.00	.70100	.49070	217A	
CAPACITOR, FOIL TANT, CL	3.0	50	8.00	.16750	4.02000	217A	
COIL, RF	8.0	50	8.60	.22000	15.13600	217A	
DIODE, SILICON, 0-1 WATT	8.0	50	3.50	.41000	11.48000	217A	
DIODE, SILICON, 1-50 WATT	1.0	50	12.00	.90000	10.80000	217A	
FILTER, FEED THRU	9.0	50	1.00	.30000	2.70000	217A	
RESISTOR, FIXED CARBON COMPOSITION	8.0	50	10.00	.02650	.21200	217A	
RESISTOR, FIXED METAL FILM	4.0	50	.30	.24850	.29820	217A	
TRANSFORMER, RF	1.0	50	10.00	.22000	2.20000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	50	8.00	.82000	6.56000	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	50	8.00	1.25000	20.00000	217A	
ZENER DIODE, 0-1 WATT	1.0	50	3.00	1.25000	3.75000	217A	

TOTAL FAILURE RATE EQUALS   81.07108 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   12334.8555 HOURS

DESIGN FAILURE RATE GOAL   45.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RF/IF   MODEL R/T UNIT

DATE APR 12,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	60	5.00	.00962	.72113	217A	
	CAPACITOR, MICA, CM	2.0	60	15.00	.00036	.01072	217A	
	COIL, RF	1.0	50	8.60	.22000	1.89200	217A	
	CONNECTOR, RF	3.5	50	4.00	.04000	.56000	217A	
	CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	
	INTEGRATED CIRCUIT, LINEAR	5.0	50	1.00	.40000	2.00000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	50	10.00	.02650	.50350	217A	
S3	RESISTOR, NON-WW VAR. L. S. ACT.	1.0	50	2.00	49.12999	9.82600	217A	1
	DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
	TRANSFORMER, RF	2.0	50	10.00	.22000	4.40000	217A	
	CAPACITOR, VAR AIR, CT	2.0	50	1.00	.24700	.49400	217A	

TOTAL FAILURE RATE EQUALS 36.01131 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 27769.0547 HOURS

DESIGN FAILURE RATE GOAL 20.00000 FAILURES PER MILLION HOURS

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE
DUE TO NO FIELD ADJUSTMENTS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER AMPLIFIER   MODEL R/T UNIT

DATE APR 12,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	61.0	30	5.00	.01098	3.35042	217A	
	COIL, RF	24.0	30	8.60	.22000	45.40800	217A	
	CONNECTOR, RF	6.0	30	4.00	.04000	.96000	217A	
	DIODE, HOT CARRIER	3.0	30	3.50	.65000	6.82500	217A	
	DIODE, SILICON, 0-1 WATT	8.0	30	3.50	.25500	7.14000	217A	
S.	RESISTOR, FIXED CARBON COMPOSITION	33.0	30	10.00	.01193	.39353	217A	
	TRANSFORMER, RF	10.0	30	10.00	.22000	22.00000	217A	
	TRANSISTOR, FIELD EFFECT	9.0	30	8.00	.67000	48.23999	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	9.0	30	8.00	.51000	36.71999	217A	

TOTAL FAILURE RATE EQUALS 173.07690 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 5777.7773 HOURS

DESIGN FAILURE RATE GOAL 97.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE XMTR MODULATOR   MODEL R/T UNIT

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	6.0	60	5.00	.00962	.28845	217A	
CAPACITOR, SLD TANT, CSR	2.0	50	1.00	.70100	.14020	217A	
COIL, RF	2.0	50	8.60	.22000	3.78400	217A	
DIODE, HOT CARRIER	8.0	50	3.50	1.03000	28.83998	217A	
DIODE, SILICON, 0-1 WATT	10.0	50	3.50	.41000	14.35000	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	50	1.00	.40000	.80000	217A	
RELAY, HALF CRYSTAL CAN	3.0	50	50.00	.00310	.46500	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	30.0	50	10.00	.02650	.79500	217A	
TRANSFORMER, RF	4.0	50	10.00	.22000	8.80000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	10.0	50	8.00	.41000	32.79999	217A	
ZENER DIODE, 0-1 WATT	1.0	50	3.00	1.25000	3.75000	217A	

TOTAL FAILURE RATE EQUALS   94.81258 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   10547.1211 HOURS

DESIGN FAILURE RATE GOAL   53.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE FREQ SYN 1 MODEL R/T UNIT

DATE APR 12,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	60	5.00	.00962	1.05765	217A	
CAPACITOR, MICA, CM	16.0	60	15.00	.00036	.08580	217A	
COIL, RF	8.0	50	8.60	.22000	15.13600	217A	
DIODE, HOT CARRIER	12.0	50	3.50	1.03000	43.25998	217A	
DIODE, SILICON, 0-1 WATT	5.0	50	3.50	.41000	7.17500	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	50	1.00	.40000	.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	57.0	50	10.00	.02650	1.51050	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	50	8.00	.41000	19.67999	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	50	8.00	1.25000	20.00000	217A	
TRANSFORMER, RF	4.0	50	10.00	.22000	8.80000	217A	
RESISTOR,VARIABLE,10-TURN	1.0	50	2.00	2.03900	4.07800	SM-188	

TOTAL FAILURE RATE EQUALS 121.58287 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 8224.8398 HOURS

DESIGN FAILURE RATE GOAL 68.00000 FAILURES PER MILLION HOURS

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MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREQ SYN 2 (REC)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	60	5.00	.00962	1.05765	217A	
CAPACITOR, MICA, CM	15.0	60	15.00	.00036	.08580	217A	
COIL, RF	8.0	50	8.60	.22000	15.13600	217A	
DIODE, HOT CARRIER	12.0	50	3.50	1.03000	43.25998	217A	
DIODE, SILICON, 0-1 WATT	5.0	50	3.50	.41000	7.17500	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	50	1.00	.40000	.80000	217A	
RESISTOR, FIXED CARBON COMPOSITION	57.0	50	10.00	.02650	1.51050	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	50	8.00	.41000	19.67999	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	50	8.00	1.25000	20.00000	217A	
TRANSFORMER, RF	4.0	50	10.00	.22000	8.80000	217A	
RESISTOR,VARIABLE,10-TURN	1.0	50	2.00	2.03900	4.07800	SM-188	
CONNECTOR, RF	3.0	50	4.00	.04000	.48000	217A	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 123.09186 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 8124.0117 HOURS

S+

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CARRIER IC/VCO   MODEL R/T UNIT

DATE APR 12,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	2.0	50	1.00	.24700	.49400	217A	
	CAPACITOR, CER, CK	72.0	60	5.00	.00962	3.46140	217A	
	CAPACITOR, MICA, CM	14.0	60	15.00	.00036	.07507	217A	
	COIL, RF	6.0	50	8.60	.22000	11.35200	217A	
	CONNECTOR, RF	3.0	50	4.00	.04000	.48000	217A	
	CONNECTOR, 8 PINS	.5	50	6.00	.18200	.54600	217A	
	DIODE, SILICON, 0-1 WATT	5.0	50	3.50	.41000	7.17500	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	50	1.00	.40000	1.20000	217A	
	INTEGRATED CIRCUIT, LINEAR	19.0	50	1.00	.40000	7.60000	217A	
S*	RESISTOR, FIXED CARBON COMPOSITION	80.0	50	10.00	.02650	2.12000	217A	
	RESISTOR, FIXED METAL FILM	27.0	50	.30	.24850	2.01285	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	3.0	50	18.00	.17075	9.22050	RADC	
	TRANSISTOR, SILICON NPN, 0-1 WATT	5.0	50	8.00	.41000	16.39999	217A	
	ZENER DIODE, 0-1 WATT	3.0	50	3.00	1.25000	11.25000	217A	
	DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
	TRANSFORMER, RF	2.0	50	10.00	.22000	4.40000	217A	
	CRYSTAL, QUARTZ	3.0	50	1.00	.02000	.06000	217A	
	CAPACITOR, T C CER, CC	4.0	50	5.00	.06200	1.24000	217A	
	CAPACITOR, VAR GLASS, PC	1.0	50	20.00	.24250	4.85000	217A	
	CAPACITOR, VAR CER, CV	1.0	50	1.00	.24700	.24700	217A	
S*	RESISTOR, FIXED METAL FILM	2.0	50	.30	.24850	.00149	217A	

TOTAL FAILURE RATE EQUALS   98.60519 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   10141.4531 HOURS

DESIGN FAILURE RATE GOAL   55.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CODE DETECTOR MODEL R/T UNIT

DATE APR 12,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	46.0	60	5.00	.00962	2.21145	217A-	
CAPACITOR, MICA, CM	4.0	60	15.00	.00036	.02145	217A-	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A-	
DIODE, SILICON, 0-1 WATT	7.0	50	3.50	.41000	10.04500	217A-	
INTEGRATED CIRCUIT, DIGITAL	3.0	50	1.00	.40000	1.20000	217A-	
INTEGRATED CIRCUIT, LINEAR	19.0	50	1.00	.40000	7.60000	217A-	
RESISTOR, FIXED METAL FILM	28.0	50	.30	.24850	2.08740	217A-	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	.17075	3.07350	RADC-	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A-	

TOTAL FAILURE RATE EQUALS 30.54776 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 32735.6211 HOURS

DESIGN FAILURE RATE GOAL 17.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CACU (DIGITAL)   MODEL R/T UNIT

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	30.0	60	5.00	.00962	1.44225	217A	
INTEGRATED CIRCUIT, DIGITAL	71.0	50	1.00	.40000	28.39999	217A	
RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	54.0	50	10.00	.02650	1.43100	217A	
CAPACITOR, MICA, CM	6.0	60	15.00	.00036	.03218	217A	
COIL, RF	3.0	50	8.60	.22000	5.67600	217A	
CONNECTOR, RF	3.0	50	4.00	.04000	.48000	217A	

TOTAL FAILURE RATE EQUALS 37.61639 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 26584.1523 HOURS

DESIGN FAILURE RATE GOAL 21.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK IC DETECTOR MODEL R/T UNIT

DATE APR 12,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	50	1.00	.24700	.24700	217A	
CAPACITOR, CER, CK	36.0	60	5.00	.00962	1.73070	217A	
CAPACITOR, MICA, CM	10.0	60	15.00	.00036	.05363	217A	
COIL, RF	6.0	50	8.60	.22000	11.35200	217A	
CONNECTOR, RF	2.5	50	4.00	.04000	.40000	217A	
CONNECTOR, 8 PINS	.5	50	6.00	.18200	.54600	217A	
DIODE, SILICON, 0-1 WATT	2.0	50	3.50	.41000	2.87000	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	50	1.00	.40000	4.80000	217A	
RESISTOR, FIXED CARBON COMPOSITION	48.0	50	10.00	.02650	1.27200	217A	
RESISTOR, FIXED METAL FILM	13.0	50	.30	.24850	.96915	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	.17075	3.07350	RADC	
TRANSFORMER, RF	6.0	50	10.00	.22000	13.20000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	2.0	50	8.00	.41000	6.56000	217A	
ZENER DIODE, 0-1 WATT	1.0	50	3.00	1.25000	3.75000	217A	
DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
CAPACITOR, T C CER, CC	4.0	50	5.00	.06200	1.24000	217A	
CRYSTAL, QUARTZ	2.0	50	1.00	.02000	.04000	217A	

TOTAL FAILURE RATE EQUALS 66.52388 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 15032.1953 HOURS

DESIGN FAILURE RATE GOAL 37.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK PHASE CONTROL MODEL R/T UNIT

DATE APR 12,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	38.0	60	5.00	.00962	1.82685	217A	
CAPACITOR, MICA, CM	4.0	60	15.00	.00036	.02145	217A	
COIL, RF	5.0	50	8.60	.22000	9.46000	217A	
DIODE, SILICON, 0-1 WATT	1.0	50	3.50	.41000	1.43500	217A	
INTEGRATED CIRCUIT, DIGITAL	4.0	50	1.00	.40000	1.60000	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	50	1.00	.40000	4.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	28.0	50	10.00	.02650	.74200	217A	
RESISTOR, FIXED METAL FILM	10.0	50	.30	.24850	.74550	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	.17075	3.07350	RADC	
TRANSFORMER, RF	5.0	50	10.00	.22000	11.00000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	
DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
CAPACITOR, T C CER, CC	8.0	50	5.00	.06200	2.48000	217A	
CRYSTAL, QUARTZ	4.0	50	1.00	.02000	.08000	217A	

TOTAL FAILURE RATE EQUALS 54.96423 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 18193.6484 HOURS

DESIGN FAILURE RATE GOAL 30.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RTJ CABLE HARNESS   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	18.0	50	4.00	.04000	2.88000	217A	
CONNECTOR, 8 PINS	2.0	50	6.00	.13200	2.18400	217A	
CONNECTOR, 15 PINS	3.0	50	6.00	.34300	6.17400	217A	
CONNECTOR, 36 PINS	1.5	50	6.00	1.22500	11.02500	217A	

TOTAL FAILURE RATE EQUALS   22.26300 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   44917.5742 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RCDU-DPU   MODEL POSITIONING SET

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	68.0	60	5.00	.00962	3.26910	217A	
CAPACITOR, T C CER, CC	2.0	50	5.00	.06200	.62000	217A	
CAPACITOR, MICA, CM	20.0	60	15.00	.00036	.10725	217A	
CAPACITOR, SLD TANT, CSR	5.0	50	1.00	.70100	.35050	217A	
COIL, AUDIO	1.0	50	10.00	.22750	2.27500	217A	
COIL, RF	3.0	50	8.60	.22000	5.67600	217A	
INTEGRATED CIRCUIT, DIGITAL	41.0	50	1.00	.40000	16.39999	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	50	1.00	.40000	4.80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	54.0	50	10.00	.02650	1.43100	217A	
RESISTOR, FIXED METAL FILM	8.0	50	.30	.24850	.59640	217A	
TRANSFORMER, RF	2.0	50	10.00	.22000	4.40000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	

TOTAL FAILURE RATE EQUALS 43.20520 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 23145.3594 HOURS

DESIGN FAILURE RATE GOAL 21.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU PWR SUP MODEL POSITIONING SET

DATE APR 12,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	50	1.00	.70100	.42060	217A	
	CAPACITOR, FOIL TANT, CL	2.0	50	8.00	.16750	2.68000	217A	
	COIL, AUDIO	1.0	50	10.00	.22750	2.27500	217A	
	DIODE, SILICON, 0-1 WATT	15.0	50	3.50	.41000	21.52499	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	50	10.00	.02650	.50350	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	50	.30	.24850	.00149	217A	
	TRANSFORMER, POWER	1.0	50	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	50	8.00	.41000	13.12000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	50	8.00	.82000	6.56000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	50	8.00	1.25000	30.00000	217A	
	ZENER DIODE, 0-1 WATT	3.0	50	3.00	1.25000	11.25000	217A	
	CAPACITOR, CER, CK	3.0	60	5.00	.00962	.14423	217A	
	CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 91.86375 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10885.6836 HOURS

DESIGN FAILURE RATE GOAL 46.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU WORD CONTROL MODEL POSITIONING SET

DATE APR 12,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	60	5.00	.00962	.72113	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	44.0	50	1.00	.40000	17.59999	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	5.0	50	10.00	.02650	.13250	217A	

TOTAL FAILURE RATE EQUALS 25.80360 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 38754.2734 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

AD-A047 145 MOTOROLA INC SCOTTSDALE ARIZ GOVERNMENT ELECTRONICS DIV F/G 17/3
LRPDS INTERIM TECHNICAL REPORT. APPENDICES,(U)
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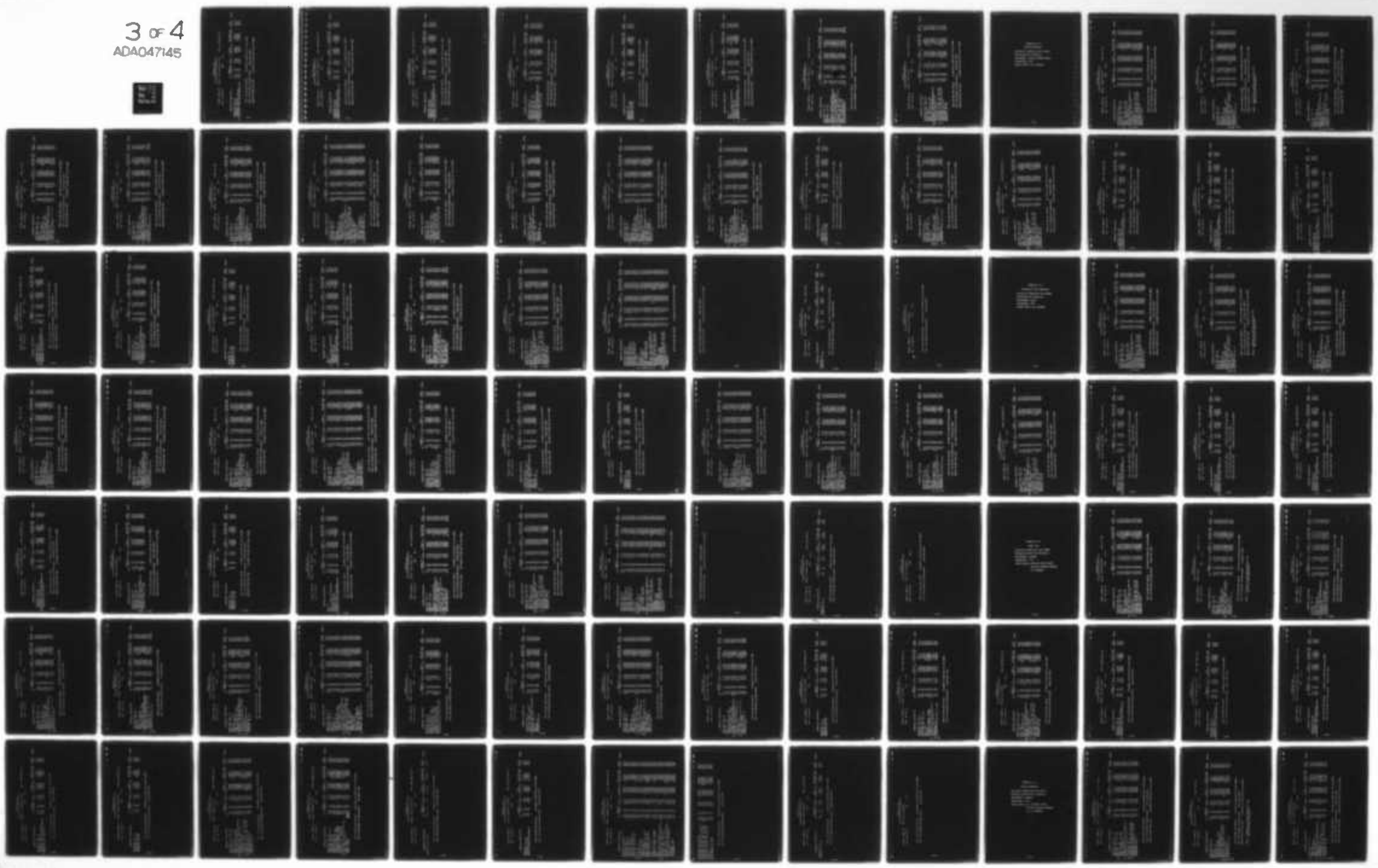

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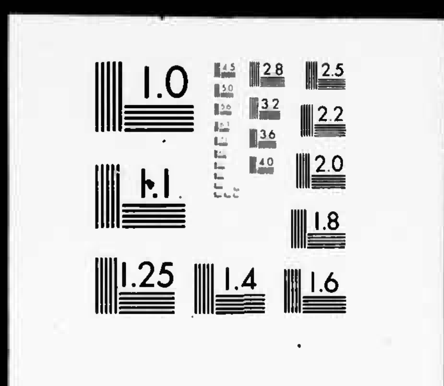

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU MSG OUTPUT CTRL   MODEL POSITIONING SET

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	16.0	60	5.00	.00962	.76920	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	47.0	50	1.00	.40000	18.79999	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	18.0	50	10.00	.02650	.47700	217A	

TOTAL FAILURE RATE EQUALS   27.39618 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   36501.4375 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU DATA ASMBLR & ST   MODEL POSITIONING SET

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	60	5.00	.00962	.72113	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	46.0	50	1.00	.40000	18.39999	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	6.0	50	10.00	.02650	.15900	217A	

TOTAL FAILURE RATE EQUALS   26.63011 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   37551.4727 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPJ COMMAND DECODER   MODEL POSITIONING SET

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	14.0	60	5.00	.00962	.67305	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	44.0	50	1.00	.40000	17.59999	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	20.0	50	10.00	.02650	.53000	217A	
CAPACITOR, SLD TANT, CSR	1.0	50	1.00	.70100	.07010	217A	

TOTAL FAILURE RATE EQUALS 26.22313 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 38134.2734 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU MEMORY MODEL POSITIONING SET

DATE APR 12,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, GLASS, CY	5.0	80	18.00	.12040	10.83600	217A	
	CAPACITOR, CER, CK	34.0	60	5.00	.00962	1.63455	217A	
	CAPACITOR, SLD TANT, CSR	7.0	50	1.00	.70100	.49070	217A	
	CONNECTOR, 36 PINS	.5	50	6.00	1.22500	3.67500	217A	
	INTEGRATED CIRCUIT, DIGITAL	59.0	50	1.00	.40000	23.59999	217A	
S	RESISTOR, FIXED CARBON COMPOSITION	18.0	50	10.00	.02650	.47700	217A	
S	RESISTOR, FIXED METAL FILM	4.0	50	.30	.24850	.00298	217A	
	INTEGRATED CIRCUIT, LINEAR	8.0	50	1.00	.40000	3.20000	217A	

TOTAL FAILURE RATE EQUALS 43.91620 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 22770.6406 HOURS

DESIGN FAILURE RATE GOAL 22.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CABLE HARNESS-DPJ   MODEL POSITIONING SET

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	.5	50	4.00	.04000	.08000	217A	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	
CONNECTOR, 36 PINS	7.0	50	6.00	1.22500	51.45001	217A	
CONNECTOR, 20 PINS	.5	50	6.00	.48600	1.45800	217A	

TOTAL FAILURE RATE EQUALS 54.01700 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 18512.6875 HOURS

DESIGN FAILURE RATE GOAL 27.00000 FAILURES PER MILLION HOURS

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MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CONTROL PANEL-DPJ   MODEL POSITIONING SET

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
COIL, RF	6.0	50	8.60	.22000	11.35200	217A	
FUSE	1.0	50	1.00	.10000	.10000	217A	
SWITCH, TOGGLE OR PUSHBUTTON	46.0	50	18.00	.25000	207.00000	217A	
CAPACITOR, CER, CK	12.0	60	5.00	.00962	.57690	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	66.0	50	1.00	.40000	26.39999	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	162.0	50	10.00	.02650	4.29300	217A	

TOTAL FAILURE RATE EQUALS 257.07178 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 3889.9641 HOURS

DESIGN FAILURE RATE GOAL 172.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DATA DISPLY UNIT   MODEL POSITIONING SET

DATE MAY 04,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	20.0	50	5.00	.02425	2.42500	217A	
COIL, RF	2.0	50	8.60	.22000	3.78400	217A	
CONNECTOR, 10 PINS	.5	50	6.00	.22200	.66600	217A	
FUSE	2.0	50	1.00	.10000	.20000	217A	
INTEGRATED CIRCUIT, DIGITAL	31.0	50	1.00	.40000	12.40000	217A	
RESISTOR, FIXED CARBON COMPOSITION	5.0	50	10.00	.02650	.13250	217A	
RESISTOR, VARIABLE CARBON COMP.	1.0	50	50.00	.12650	6.32500	217A	
SWITCH, TOGGLE OR PUSHBUTTON	2.0	50	18.00	.25000	9.00000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	2.0	50	8.00	.82000	13.12000	217A	
CAPACITOR, SLD TANT, CSR	4.0	50	1.00	.75050	.30020	217A	
DIODE, SILICON, 0-1 WATT	6.0	50	3.50	.41000	8.61000	217A	
RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
INDICATOR,HP5082-7000	20.0	50	1.00	.80580	16.11600	SM-188	

TOTAL FAILURE RATE EQUALS 73.23364 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 13654.9258 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DDU PWR SUP MODEL POSITIONING SET

DATE APR 12,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	50	1.00	.70100	.42060	217A	
	CAPACITOR, FOIL TANT, CL	2.0	50	8.00	.16750	2.68000	217A	
	COIL, AUDIO	1.0	50	10.00	.22750	2.27500	217A	
	DIODE, SILICON, 0-1 WATT	15.0	50	3.50	.41000	21.52499	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	50	10.00	.02650	.50350	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	50	.30	.24850	.00149	217A	
	TRANSFORMER, POWER	1.0	50	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	50	8.00	.41000	13.12000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	50	8.00	.82000	6.56000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	50	8.00	1.25000	30.00000	217A	
	ZENER DIODE, 0-1 WATT	3.0	50	3.00	1.25000	11.25000	217A	
	CAPACITOR, CER, CK	3.0	60	5.00	.00962	.14423	217A	
	CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 91.86375 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10885.6836 HOURS

DESIGN FAILURE RATE GOAL 44.00000 FAILURES PER MILLION HOURS

APPENDIX F-4.2

TYPICAL OPERATION

RELIABILITY PREDICTION DATA SHEETS

POSITIONING SET AN/PSQ-101

ENVIRONMENT: VEHICLE MOUNTED GROUND

TEMPERATURE: +50°C

STRESS LEVELS: 30% (ASSUMED)

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER CONVERTER   MODEL R/T UNIT

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	3.0	30	5.00	.00640	.09600	217A	
	CAPACITOR, SLD TANT, CSR	9.0	30	1.00	.17000	.15300	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	8.00	.08650	1.38400	217A	
S3	COIL, RF	8.0	30	8.60	.22000	4.54080	217A	
	DIODE, SILICON, 0-1 WATT	8.0	30	3.50	.25500	7.14000	217A	
	DIODE, SILICON, 1-50 WATT	1.0	30	12.00	.43000	5.16000	217A	
	FILTER, FEED THRU	9.0	30	1.00	.02400	.21600	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	8.0	30	10.00	.00400	.03200	217A	
	RESISTOR, FIXED METAL FILM	4.0	30	.30	.17000	.20400	217A	
	TRANSFORMER, RF	1.0	30	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	8.00	.51000	4.08000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	8.00	.67000	10.72000	217A	
	ZENER DIODE, 0-1 WATT	1.0	30	3.00	.77000	2.31000	217A	
	CONNECTOR, 8 PINS	1.0	30	6.00	.18200	1.09200	217A	

TOTAL FAILURE RATE EQUALS   41.36771 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   24173.4453 HOURS

DESIGN FAILURE RATE GOAL   44.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RF/IF   MODEL R/T UNIT

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	5.00	.00640	.48000	217A	
	CAPACITOR, MICA, CM	2.0	30	15.00	.00071	.02145	217A	
	COIL, RF	1.0	30	8.60	.22000	1.89200	217A	
	CONNECTOR, RF	3.5	30	4.00	.04000	.56000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
	INTEGRATED CIRCUIT, LINEAR	5.0	30	1.00	.40000	2.00000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	10.00	.00400	.07600	217A	
S3	RESISTOR, NON-WW VAR. _. S. ACT.	1.0	30	2.00	39.30000	7.86000	217A	1
S3	DIODE, HOT CARRIER	4.0	30	3.50	.65000	2.73000	217A	
S3	TRANSFORMER, RF	2.0	30	10.00	.22000	1.32000	217A	
	CAPACITOR, VAR AIR, CT	2.0	30	1.00	.03500	.07000	217A	

TOTAL FAILURE RATE EQUALS   18.19342 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   54964.9219 HOURS

DESIGN FAILURE RATE GOAL   19.00000 FAILURES PER MILLION HOURS

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE
DUE TO NO FIELD ADJUSTMENTS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE POWER AMPLIFIER MODEL R/T UNIT

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	61.0	30	5.00	.00640	1.95200	217A	
S3	COIL, RF	24.0	30	8.60	.22000	13.62241	217A	
	CONNECTOR, RF	1.5	30	4.00	.04000	.24000	217A	
	DIODE, HOT CARRIER	3.0	30	3.50	.65000	6.82500	217A	
	DIODE, SILICON, 0-1 WATT	8.0	30	3.50	.25500	7.14000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	33.0	30	10.00	.00400	.13200	217A	
	TRANSFORMER, RF	10.0	30	10.00	.22000	22.00000	217A	
S3	TRANSISTOR, FIELD EFFECT	9.0	30	8.00	.67000	14.47200	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
S3	TRANSISTOR, SILICON NPN, 1-50 WATT	9.0	30	8.00	.51000	11.01601	217A	
	CONNECTOR, 36 PINS	.5	30	6.00	1.22500	3.67500	217A	

TOTAL FAILURE RATE EQUALS 83.11436 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 12031.6133 HOURS

DESIGN FAILURE RATE GOAL 95.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE XMTR MODULATOR MODEL R/T UNIT

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	6.0	30	5.00	.00640	.19200	217A	
	CAPACITOR, SLD TANT, CSR	2.0	30	1.00	.17000	.03400	217A	
	COIL, RF	2.0	30	8.60	.22000	3.78400	217A	
	DIODE, HOT CARRIER	8.0	30	3.50	.65000	18.20000	217A	
	DIODE, SILICON, 0-1 WATT	10.0	30	3.50	.25500	8.92500	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
	RELAY, HALF CRYSTAL CAN	3.0	30	50.00	.00310	.46500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	30.0	30	10.00	.00400	.12000	217A	
	TRANSFORMER, RF	4.0	30	10.00	.22000	8.80000	217A	
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	10.0	30	8.00	.25500	6.12000	217A	
	ZENER DIODE, 0-1 WATT	1.0	30	3.00	.77000	2.31000	217A	

TOTAL FAILURE RATE EQUALS 49.74994 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 20100.5234 HOURS

DESIGN FAILURE RATE GOAL 52.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREQ SYN 1 (XMTR)   MODEL R/T UNIT

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	22.0	30	5.00	.00640	.70400	217A	
	CAPACITOR, MICA, CM	16.0	30	15.00	.00071	.17160	217A	
	COIL, RF	8.0	30	8.60	.22000	15.13600	217A	
S3	DIODE, HOT CARRIER	12.0	30	3.50	.65000	8.19000	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	57.0	30	10.00	.00400	.22800	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	8.00	.25500	12.24000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	8.00	.67000	10.72000	217A	
	TRANSFORMER, RF	4.0	30	10.00	.22000	8.80000	217A	
	RESISTOR, VARIABLE, 10-TURN	1.0	30	2.00	1.51000	3.02000	SM-188	

TOTAL FAILURE RATE EQUALS   64.47203 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   15510.6016 HOURS

DESIGN FAILURE RATE GOAL   66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREQ SYN 2 (REC)   MODEL R/T UNIT

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	22.0	30	5.00	.00640	.70400	217A	
	CAPACITOR, MICA, CM	16.0	30	15.00	.00071	.17160	217A	
S3	COIL, RF	8.0	30	8.60	.22000	4.54080	217A	
S3	DIODE, HOT CARRIER	12.0	30	3.50	.65000	8.19000	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	57.0	30	10.00	.00400	.22800	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	8.00	.25500	12.24000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	8.00	.67000	10.72000	217A	
	TRANSFORMER, RF	4.0	30	10.00	.22000	8.80000	217A	
	RESISTOR, VARIABLE, 10-TURN	1.0	50	2.00	1.58500	3.17000	SM-188	
	CONNECTOR, RF	3.0	30	4.00	.04000	.48000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 55.53581 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 18006.3984 HOURS

DESIGN FAILURE RATE GOAL 66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CARRIER IO/VCO   MODEL R/T UNIT

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	2.0	30	1.00	.03500	.07000	217A	
	CAPACITOR, CER, CK	72.0	30	5.00	.00640	2.30400	217A	
	CAPACITOR, MICA, CM	14.0	30	15.00	.00071	.15015	217A	
S3	COIL, RF	6.0	30	8.60	.22000	3.40560	217A	
	CONNECTOR, RF	3.0	30	4.00	.04000	.48000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
	INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	7.60000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	80.0	30	10.00	.00400	.32000	217A	
	RESISTOR, FIXED METAL FILM	27.0	30	.30	.17000	1.37700	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	3.0	30	18.00	.09600	5.18400	RADC	
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	5.0	30	8.00	.25500	3.06000	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	3.00	.77000	6.93000	217A	
	DIODE, HOT CARRIER	4.0	30	3.50	.65000	9.10000	217A	
	TRANSFORMER, RF	2.0	30	10.00	.22000	4.40000	217A	
	CRYSTAL, QUARTZ	3.0	30	1.00	.02000	.06000	217A	
	CAPACITOR, T C CER, CC	4.0	30	5.00	.00625	.12500	217A	
	CAPACITOR, VAR GLASS, PC	1.0	30	20.00	.05850	1.17000	217A	
	CAPACITOR, VAR CER, CV	1.0	30	1.00	.03500	.03500	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.30	.17000	.00102	217A	

TOTAL FAILURE RATE EQUALS 52.46315 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 19060.9961 HOURS

DESIGN FAILURE RATE GOAL 54.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CODE DETECTOR MODEL R/T UNIT

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	46.0	30	5.00	.00640	1.47200	217A	
	CAPACITOR, MICA, CM	4.0	30	15.00	.00071	.04290	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
S3	DIODE, SILICON, 0-1 WATT	7.0	30	3.50	.25500	1.87425	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
S3	INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	2.28000	217A	
	RESISTOR, FIXED METAL FILM	28.0	30	.30	.17000	1.42800	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.09600	1.72800	RADC	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	

TOTAL FAILURE RATE EQUALS 13.09411 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 76370.1875 HOURS

DESIGN FAILURE RATE GOAL 16.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CACU (DIGITAL) MODEL R/T UNIT

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	30.0	30	5.00	.00640	.96000	217A	
S4	INTEGRATED CIRCUIT, DIGITAL	71.0	30	1.00	.40000	2.84000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	10.00	.00400	.21600	217A	
	CAPACITOR, MICA, CM	6.0	30	15.00	.00071	.06435	217A	
	COIL, RF	3.0	30	8.60	.22000	5.67600	217A	
	CONNECTOR, RF	6.0	30	4.00	.04000	.96000	217A	
	CONNECTOR, 36 PINS	.5	30	6.00	1.22500	3.67500	217A	

TOTAL FAILURE RATE EQUALS 14.54630 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 68745.9375 HOURS

DESIGN FAILURE RATE GOAL 20.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK IG DETECTOR MODEL R/T UNIT

DATE APR 20,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	30	1.00	.03500	.03500	217A	
CAPACITOR, CER, CK	36.0	30	5.00	.00640	1.15200	217A	
CAPACITOR, MICA, CM	10.0	30	15.00	.00071	.10725	217A	
S3 COIL, RF	6.0	30	8.60	.22000	3.40560	217A	
CONNECTOR, RF	3.0	30	4.00	.04000	.48000	217A	
CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
DIODE, SILICON, 0-1 WATT	2.0	30	3.50	.25500	1.78500	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	48.0	30	10.00	.00400	.19200	217A	
RESISTOR, FIXED METAL FILM	13.0	30	.30	.17000	.66300	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.09600	1.72800	RADC	
S3 TRANSFORMER, RF	6.0	30	10.00	.22000	3.96000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	2.0	30	8.00	.25500	4.08000	217A	
ZENER DIODE, 0-1 WATT	1.0	30	3.00	.77000	2.31000	217A	
DIODE, HOT CARRIER	4.0	30	3.50	.65000	9.10000	217A	
CAPACITOR, T C CER, CC	4.0	30	5.00	.00625	.12500	217A	
CRYSTAL, QUARTZ	2.0	30	1.00	.02000	.04000	217A	

TOTAL FAILURE RATE EQUALS 34.99174 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 28578.1680 HOURS

DESIGN FAILURE RATE GOAL 36.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CLOCK PHASE CONTROL   MODEL R/T UNIT

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	38.0	30	5.00	.00640	1.21600	217A	
	CAPACITOR, MICA, CM	4.0	30	15.00	.00071	.04290	217A	
S3	COIL, RF	5.0	30	8.60	.22000	2.83800	217A	
	DIODE, SILICON, 0-1 WATT	1.0	30	3.50	.25500	.89250	217A	
	INTEGRATED CIRCUIT, DIGITAL	4.0	30	1.00	.40000	1.60000	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	28.0	30	10.00	.00400	.11200	217A	
	RESISTOR, FIXED METAL FILM	10.0	30	.30	.17000	.51000	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.09600	1.72800	RADC	
S3	TRANSFORMER, RF	5.0	30	10.00	.22000	3.30000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
	DIODE, HOT CARRIER	4.0	30	3.50	.65000	9.10000	217A	
	CAPACITOR, T C CER, CC	8.0	30	5.00	.00625	.25000	217A	
	CRYSTAL, QUARTZ	4.0	30	1.00	.02000	.08000	217A	

TOTAL FAILURE RATE EQUALS   28.50932 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   35076.2422 HOURS

DESIGN FAILURE RATE GOAL   30.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RTJ CABLE HARNESS MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CONNECTOR, RF	18.0	30	4.00	.04000	2.88000	217A	
	CONNECTOR, 8 PINS	2.0	30	6.00	.18200	2.18400	217A	
S3	CONNECTOR, 15 PINS	3.0	30	6.00	.34300	1.85220	217A	
S3	CONNECTOR, 36 PINS	1.5	30	6.00	1.22500	3.30750	217A	

TOTAL FAILURE RATE EQUALS 10.22370 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 97811.9375 HOURS

DESIGN FAILURE RATE GOAL 12.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RCDU-DPU MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	68.0	30	5.00	.00640	2.17600	217A	
	CAPACITOR, T C CER, CC	2.0	30	5.00	.00625	.06250	217A	
	CAPACITOR, MICA, CM	20.0	30	15.00	.00071	.21450	217A	
	CAPACITOR, SLD TANT, CSR	5.0	30	1.00	.17000	.08500	217A	
	COIL, AUDIO	1.0	30	10.00	.20000	2.00000	217A	
S3	COIL, RF	3.0	30	8.60	.22000	1.70280	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	.40000	4.92000	217A	
S3	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	1.44000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	10.00	.00400	.21600	217A	
	RESISTOR, FIXED METAL FILM	6.0	30	.30	.17000	.40800	217A	
	TRANSFORMER, RF	2.0	30	10.00	.22000	4.40000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	

TOTAL FAILURE RATE EQUALS 19.66473 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 50852.4531 HOURS

DESIGN FAILURE RATE GOAL 21.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU PWR SUP MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.17000	.10200	217A	
CAPACITOR, FOIL TANT, CL	2.0	30	8.00	.08650	1.38400	217A	
COIL, AUDIO	1.0	30	10.00	.20000	2.00000	217A	
DIODE, SILICON, 0-1 WATT	15.0	30	3.50	.25500	13.38750	217A	
RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	19.0	30	10.00	.00400	.07600	217A	
S4 RESISTOR, FIXED METAL FILM	2.0	30	.30	.17000	.00102	217A	
TRANSFORMER, POWER	1.0	30	10.00	.22000	2.20000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	8.00	.25500	8.16000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	8.00	.51000	4.08000	217A	
S3 TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	8.00	.67000	4.82400	217A	
ZENER DIODE, 0-1 WATT	3.0	30	3.00	.77000	6.93000	217A	
CAPACITOR, CER, CK	3.0	30	5.00	.00640	.09600	217A	
CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 44.42442 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 22510.1367 HOURS

DESIGN FAILURE RATE GOAL 46.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU WORD CONTROL MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	30	5.00	.00640	.48000	217A	
S3 CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3 INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	5.0	30	10.00	.00400	.02000	217A	

TOTAL FAILURE RATE EQUALS 7.98499 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 125235.0000 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPJ MSG OUTPUT CTRL   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	16.0	30	5.00	.00640	.51200	217A	
S3 CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3 INTEGRATED CIRCUIT, DIGITAL	47.0	30	1.00	.40000	5.64000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	18.0	30	10.00	.00400	.07200	217A	

TOTAL FAILURE RATE EQUALS   8.42899 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   118638.1875 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU DATA ASMBLR & ST MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	30	5.00	.00640	.48000	217A	
CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
INTEGRATED CIRCUIT, DIGITAL	46.0	30	1.00	.40000	5.52000	217A	
RESISTOR, FIXED CARBON COMPOSITION	6.0	30	10.00	.00400	.02400	217A	

TOTAL FAILURE RATE EQUALS 8.22899 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 121521.6250 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU COMMAND DECODER MODEL POSITIONING SET

DATE APR 20, '71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	14.0	30	5.00	.00640	.44800	217A	
S3	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	20.0	30	10.00	.00400	.08000	217A	
	CAPACITOR, SLD TANT, CSR	1.0	30	1.00	.17000	.01700	217A	

TOTAL FAILURE RATE EQUALS 8.02997 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 124533.4375 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU MEMORY   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, GLASS, CY	5.0	30	18.00	.02300	2.07000	217A	
	CAPACITOR, CER, CK	34.0	30	5.00	.00640	1.08800	217A	
	CAPACITOR, SLD TANT, CSR	7.0	30	1.00	.17000	.11900	217A	
	CONNECTOR, 36 PINS	.5	30	6.00	1.22500	3.67500	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	59.0	30	1.00	.40000	7.08000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	18.0	30	10.00	.00400	.07200	217A	
S4	RESISTOR, FIXED METAL FILM	4.0	30	.30	.17000	.00204	217A	
	INTEGRATED CIRCUIT, LINEAR	8.0	30	1.00	.40000	3.20000	217A	

TOTAL FAILURE RATE EQUALS   17.30602 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   57783.3750 HOURS

DESIGN FAILURE RATE GOAL   22.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CABLE HARNESS-DPU MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	2.0	30	4.00	.04000	.32000	217A	
CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
S3 CONNECTOR, 36 PINS	7.0	30	6.00	1.22500	15.43501	217A	
CONNECTOR, 20 PINS	.5	30	6.00	.48600	1.45800	217A	

TOTAL FAILURE RATE EQUALS 18.24200 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 54818.5352 HOURS

DESIGN FAILURE RATE GOAL 27.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CONTROL PANEL-OPU   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	COIL, RF	6.0	30	8.60	.22000	11.35200	217A	
	FUSE	1.0	30	1.00	.10000	.10000	217A	
S3	SWITCH, TOGGLE OR PUSHBUTTON	46.0	30	18.00	.25000	62.10001	217A	
	CAPACITOR, CER, CK	12.0	30	5.00	.00640	.38400	217A	
	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	7.35000	217A	
	INTEGRATED CIRCUIT, DIGITAL	66.0	30	1.00	.40000	26.39999	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	162.0	30	10.00	.00400	.64800	217A	

TOTAL FAILURE RATE EQUALS 108.33397 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 9230.7148 HOURS

DESIGN FAILURE RATE GOAL 172.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995.113 MODULE DATA DISPLY UNIT MODEL POSITIONING SET

DATE MAY 04,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	20.0	30	5.00	.00640	.64000	217A	
COIL, RF	2.0	30	8.60	.22000	3.78400	217A	
CONNECTOR, 10 PINS	.5	30	6.00	.22200	.66600	217A	
FUSE	2.0	30	1.00	.10000	.20000	217A	
INTEGRATED CIRCUIT, DIGITAL	31.0	30	1.00	.40000	12.40000	217A	
RESISTOR, FIXED CARBON COMPOSITION	5.0	30	10.00	.00400	.02000	217A	
RESISTOR, VARIABLE CARBON COMP.	1.0	30	50.00	.10000	5.00000	217A	
SWITCH, TOGGLE OR PUSHBUTTON	2.0	30	18.00	.25000	9.00000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	2.0	30	8.00	.51000	8.16000	217A	
CAPACITOR, SLD TANT, CSR	4.0	30	1.00	.17000	.06800	217A	
DIODE, SILICON, 0-1 WATT	6.0	30	3.50	.25500	5.35500	217A	
RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
INDICATOR,HP5082-7000	20.0	30	1.00	.80580	16.11600	SM-188	

TOTAL FAILURE RATE EQUALS 61.56395 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 16243.2695 HOURS

DESIGN FAILURE RATE GOAL 127.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DDU PWR SUP MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.17000	.10200	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	8.00	.08650	1.38400	217A	
	COIL, AUDIO	1.0	30	10.00	.20000	2.00000	217A	
S3	DIODE, SILICON, 0-1 WATT	15.0	30	3.50	.25500	4.01625	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	10.00	.00400	.07600	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.30	.17000	.00102	217A	
	TRANSFORMER, POWER	1.0	30	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	8.00	.25500	8.16000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	8.00	.51000	4.08000	217A	
S3	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	8.00	.67000	4.82400	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	3.00	.77000	6.93000	217A	
	CAPACITOR, CER, CK	3.0	30	5.00	.00640	.09600	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 35.05316 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 28528.0937 HOURS

DESIGN FAILURE RATE GOAL 44.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CRYSTAL OSC MODEL POSITIONING SET

DATE APR 20,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, GLASS, CY	5.0	30	18.00	.02300	2.07000	217A	
	CAPACITOR, CER, CK	29.0	30	5.00	.00640	.92800	217A	
	CAPACITOR, MICA, CM	7.0	30	15.00	.00071	.07507	217A	
	CAPACITOR, VAR GLASS, PC	1.0	30	20.00	.05850	1.17000	217A	
	CAPACITOR, MYLAR, CTM	4.0	30	10.00	.00125	.05000	217A	
	CAPACITOR, SLD TANT, CSR	12.0	30	1.00	.17000	.20400	217A	
	CAPACITOR, VAR CER, CV	4.0	30	1.00	.03500	.14000	217A	
	COIL, AUDIO	2.0	30	10.00	.20000	4.00000	217A	
S3	COIL, RF	6.0	30	8.60	.22000	3.40560	217A	
	CONNECTOR, RF	4.0	30	4.00	.04000	.64000	217A	
	CONNECTOR, 8 PINS	1.0	30	6.00	.18200	1.09200	217A	
	CRYSTAL, QUARTZ	2.0	30	1.00	.02000	.04000	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
S3	DIODE, SILICON, 1-50 WATT	3.0	30	12.00	.43000	4.64400	217A	
	FUSE	2.0	30	1.00	.10000	.20000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	1.0	30	10.00	.00400	.00400	217A	
	RESISTOR, FIXED METAL FILM	51.0	30	.30	.17000	2.60100	217A	
S3	RESISTOR, NON-WW VAR. L. S. ACT.	3.0	30	2.00	39.30000	23.58002	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	2.0	30	18.00	.09600	3.45600	RADC	
	THERMISTOR	1.0	30	1.00	.30000	.30000	217A	
	TRANSFORMER, AUDIO	2.0	30	10.00	.22000	4.40000	217A	
	TRANSFORMER, POWER	1.0	30	10.00	.22000	2.20000	217A	
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	7.0	30	8.00	.25500	4.28400	217A	
S3	TRANSISTOR, SILICON NPN, 1-50 WATT	4.0	30	8.00	.51000	4.89600	217A	
	ZENER DIODE, 0-1 WATT	2.0	30	3.00	.77000	4.62000	217A	
	THERMOSTAT	1.0	30	1.00	.20000	.20000	217A	

TOTAL FAILURE RATE EQUALS 73.66083 FAILURES PER MILLION HOURS

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MEAN TIME BETWEEN FAILURES EQUALS    13575.7344 HOURS
DESIGN FAILURE RATE GOAL      50.00000 FAILURES PER MILLION HOURS
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MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE OUTSIDE CABLES MODEL LRPDS SYSTEM

DATE APR 20,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	1.0	30	4.00	.04000	.16000	217A	
CONNECTOR, 8 PINS	2.0	30	6.00	.18200	2.18400	217A	

TOTAL FAILURE RATE EQUALS 2.34400 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 426621.3125 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   TOTAL OF ALL MODULES

DATE APR 20,'71   TEMP   50. C

TOTAL FAILURE RATE EQUALS   1051.01831 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   951.4580 HOURS

APPENDIX F-4.3

RELIABILITY TEST CONDITION

RELIABILITY PREDICTION DATA SHEETS

POSITIONING SET AN/PSQ-101

ENVIRONMENT: GROUND

TEMPERATURE: +25°C

STRESS LEVELS: 30% (ASSUMED)

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER CONVERTER   MODEL R/T UNIT

DATE APR 20,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	3.0	30	1.00	.00512	.01537	217A	
CAPACITOR, SLD TANT, CSR	9.0	30	1.00	.11000	.09900	217A	
CAPACITOR, FOIL TANT, CL	2.0	30	1.00	.06600	.13200	217A	
COIL, RF	8.0	30	1.00	.22000	1.76000	217A	
DIODE, SILICON, 0-1 WATT	8.0	30	1.50	.25500	3.06000	217A	
DIODE, SILICON, 1-50 WATT	1.0	30	1.00	.43000	.43000	217A	
FILTER, FEED THRU	9.0	30	1.00	.01000	.09000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	8.0	30	6.00	.00350	.01680	217A	
RESISTOR, FIXED METAL FILM	4.0	30	.03	.12000	.01440	217A	
TRANSFORMER, RF	1.0	30	1.50	.22000	.33000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	.51000	.51000	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	1.50	.67000	2.01000	217A	
ZENER DIODE, 0-1 WATT	1.0	30	1.00	.77000	.77000	217A	
CONNECTOR, 8 PINS	1.0	30	1.10	.18200	.20020	217A	

TOTAL FAILURE RATE EQUALS   9.82027 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   101830.1875 HOURS

DESIGN FAILURE RATE GOAL   44.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RF/IF MODEL R/T UNIT

DATE APR 20,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	1.00	.00512	.07687	217A	
	CAPACITOR, MICA, CM	2.0	30	1.40	.00052	.00145	217A	
	COIL, RF	1.0	30	1.00	.22000	.22000	217A	
	CONNECTOR, RF	3.5	30	1.10	.04000	.15400	217A	
	CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
	INTEGRATED CIRCUIT, LINEAR	5.0	30	1.00	.40000	2.00000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	6.00	.00350	.03990	217A	
S3	RESISTOR, NON-WW VAR. L. S. ACT.	1.0	30	.10	33.42499	.33425	217A	1
	DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
	TRANSFORMER, RF	2.0	30	1.50	.22000	.66000	217A	
	CAPACITOR, VAR AIR, CT	2.0	30	1.00	.02250	.04500	217A	

TOTAL FAILURE RATE EQUALS 7.62787 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 131098.1875 HOURS

DESIGN FAILURE RATE GOAL 19.00000 FAILURES PER MILLION HOURS

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE
DUE TO NO FIELD ADJUSTMENTS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE POWER AMPLIFIER MODEL R/T UNIT

DATE APR 20,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	61.0	30	1.00	.00512	.31262	217A	
COIL, RF	24.0	30	1.00	.22000	5.28000	217A	
CONNECTOR, RF	1.5	30	1.10	.04000	.06600	217A	
DIODE, HOT CARRIER	3.0	30	1.50	.65000	2.92500	217A	
DIODE, SILICON, 0-1 WATT	8.0	30	1.50	.25500	3.06000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	33.0	30	6.00	.00350	.06930	217A	
TRANSFORMER, RF	10.0	30	1.50	.22000	3.30000	217A	
TRANSISTOR, FIELD EFFECT	9.0	30	1.50	.67000	9.04500	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	9.0	30	1.00	.51000	4.59000	217A	
CONNECTOR, 36 PINS	.5	30	1.10	1.22500	.67375	217A	

TOTAL FAILURE RATE EQUALS 29.70415 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 33665.3320 HOURS

DESIGN FAILURE RATE GOAL 95.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE XMTR MODULATOR   MODEL R/T UNIT

DATE APR 20,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	6.0	30	1.00	.00512	.03075	217A	
	CAPACITOR, SLD TANT, CSR	2.0	30	1.00	.11000	.02200	217A	
	COIL, RF	2.0	30	1.00	.22000	.44000	217A	
	DIODE, HOT CARRIER	8.0	30	1.50	.65000	7.80000	217A	
	DIODE, SILICON, 0-1 WATT	10.0	30	1.50	.25500	3.82500	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
	RELAY, HALF CRYSTAL CAN	3.0	30	2.50	.00310	.02325	217A	
S*	RESISTOR, FIXED CARBON COMPOSITION	30.0	30	6.00	.00350	.06300	217A	
	TRANSFORMER, RF	4.0	30	1.50	.22000	1.32000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	10.0	30	1.50	.25500	3.82500	217A	
	ZENER DIODE, 0-1 WATT	1.0	30	1.00	.77000	.77000	217A	

TOTAL FAILURE RATE EQUALS   18.91898 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   52856.9805 HOURS

DESIGN FAILURE RATE GOAL   52.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREQ SYN 1 (XMTR)   MODEL R/T UNIT

DATE APR 20,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	30	1.00	.00512	.11275	217A	
CAPACITOR, MICA, CM	16.0	30	1.40	.00052	.01159	217A	
COIL, RF	8.0	30	1.00	.22000	1.76000	217A	
DIODE, HOT CARRIER	12.0	30	1.50	.65000	11.70000	217A	
DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	57.0	30	6.00	.00350	.11970	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	1.50	.25500	2.29500	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	1.50	.67000	2.01000	217A	
TRANSFORMER, RF	4.0	30	1.50	.22000	1.32000	217A	
RESISTOR, VARIABLE, 10-TURN	1.0	30	1.00	1.01500	1.01500	SM-188	

TOTAL FAILURE RATE EQUALS   23.05650 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   43371.7109 HOURS

DESIGN FAILURE RATE GOAL   66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE FREQ SYN 2 (REC) MODEL R/T UNIT

DATE APR 20, '71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	30	1.00	.00512	.11275	217A	
CAPACITOR, MICA, CM	16.0	30	1.40	.00052	.01159	217A	
COIL, RF	8.0	30	1.00	.22000	1.76000	217A	
DIODE, HOT CARRIER	12.0	30	1.50	.65000	11.70000	217A	
DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	57.0	30	6.00	.00350	.11970	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	1.50	.25500	2.29500	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	1.50	.67000	2.01000	217A	
TRANSFORMER, RF	4.0	30	1.50	.22000	1.32000	217A	
RESISTOR, VARIABLE, 10-TURN	1.0	50	1.00	1.05500	1.05500	SM-188	
CONNECTOR, RF	3.0	30	1.10	.04000	.13200	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	

TOTAL FAILURE RATE EQUALS 23.41713 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 42703.7813 HOURS

DESIGN FAILURE RATE GOAL 66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CARRIER IQ/VCO MODEL R/T UNIT

DATE APR 20,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	2.0	30	1.00	.02250	.04500	217A	
CAPACITOR, CER, CK	72.0	30	1.00	.00512	.36900	217A	
CAPACITOR, MICA, CM	14.0	30	1.40	.00052	.01014	217A	
COIL, RF	6.0	30	1.00	.22000	1.32000	217A	
CONNECTOR, RF	3.0	30	1.10	.04000	.13200	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	7.60000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	80.0	30	6.00	.00350	.16800	217A	
RESISTOR, FIXED METAL FILM	27.0	30	.03	.12000	.09720	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	3.0	30	18.00	.07100	3.83400	RADC	
TRANSISTOR, SILICON NPN, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
ZENER DIODE, 0-1 WATT	3.0	30	1.00	.77000	2.31000	217A	
DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
TRANSFORMER, RF	2.0	30	1.50	.22000	.66000	217A	
CRYSTAL, QUARTZ	3.0	30	1.00	.02000	.06000	217A	
CAPACITOR, T C CER, CC	4.0	30	1.00	.00275	.01100	217A	
CAPACITOR, VAR GLASS, PC	1.0	30	1.00	.02475	.02475	217A	
CAPACITOR, VAR CER, CV	1.0	30	1.00	.02250	.02250	217A	
S4 RESISTOR, FIXED METAL FILM	2.0	30	.03	.12000	.00007	217A	

TOTAL FAILURE RATE EQUALS 25.77724 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 38793.9141 HOURS

DESIGN FAILURE RATE GOAL 54.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CODE DETECTOR MODEL R/T UNIT

DATE APR 20,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	46.0	30	1.00	.00512	.23575	217A	
CAPACITOR, MICA, CM	4.0	30	1.40	.00052	.00290	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
DIODE, SILICON, 0-1 WATT	7.0	30	1.50	.25500	2.67750	217A	
INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	7.60000	217A	
RESISTOR, FIXED METAL FILM	28.0	30	.03	.12000	.10080	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	

TOTAL FAILURE RATE EQUALS 13.66609 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 73173.7500 HOURS

DESIGN FAILURE RATE GOAL 16.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CACU (DIGITAL) MODEL R/T UNIT

DATE APR 20,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	30.0	30	1.00	.00512	.15375	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	71.0	30	1.00	.40000	8.52000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	6.00	.00350	.11340	217A	
	CAPACITOR, MICA, CM	6.0	30	1.40	.00052	.00435	217A	
	COIL, RF	3.0	30	1.00	.22000	.66000	217A	
	CONNECTOR, RF	6.0	30	1.10	.04000	.26400	217A	
	CONNECTOR, 36 PINS	.5	30	1.10	1.22500	.67375	217A	

TOTAL FAILURE RATE EQUALS 10.39693 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 96182.2500 HOURS

DESIGN FAILURE RATE GOAL 20.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RTJ CABLE HARNESS MODEL POSITIONING SET

DATE APR 20,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	18.0	30	1.10	.04000	.79200	217A	
CONNECTOR, 8 PINS	2.0	30	1.10	.18200	.40040	217A	
CONNECTOR, 15 PINS	3.0	30	1.10	.34300	1.13190	217A	
CONNECTOR, 36 PINS	1.5	30	1.10	1.22500	2.02125	217A	

TOTAL FAILURE RATE EQUALS 4.34555 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 230120.4375 HOURS

DESIGN FAILURE RATE GOAL 12.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CLOCK IG DETECTOR   MODEL R/T UNIT

DATE APR 20,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	30	1.00	.02250	.02250	217A	
CAPACITOR, CER, CK	36.0	30	1.00	.00512	.18450	217A	
CAPACITOR, MICA, CM	10.0	30	1.40	.00052	.00724	217A	
COIL, RF	6.0	30	1.00	.22000	1.32000	217A	
CONNECTOR, RF	3.0	30	1.10	.04000	.13200	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
DIODE, SILICON, 0-1 WATT	2.0	30	1.50	.25500	.76500	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	48.0	30	6.00	.00350	.10080	217A	
RESISTOR, FIXED METAL FILM	13.0	30	.03	.12000	.04680	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSFORMER, RF	6.0	30	1.50	.22000	1.98000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	2.0	30	1.50	.25500	.76500	217A	
ZENER DIODE, 0-1 WATT	1.0	30	1.00	.77000	.77000	217A	
DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
CAPACITOR, T C CER, CC	4.0	30	1.00	.00275	.01100	217A	
CRYSTAL, QUARTZ	2.0	30	1.00	.02000	.04000	217A	

TOTAL FAILURE RATE EQUALS   16.31146 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   61306.5781 HOURS

DESIGN FAILURE RATE GOAL   36.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK PHASE CONTROL MODEL R/T UNIT

DATE APR 20,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	38.0	30	1.00	.00512	.19475	217A	
CAPACITOR, MICA, CM	4.0	30	1.40	.00052	.00290	217A	
COIL, RF	5.0	30	1.00	.22000	1.10000	217A	
DIODE, SILICON, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
INTEGRATED CIRCUIT, DIGITAL	4.0	30	1.00	.40000	1.60000	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	28.0	30	6.00	.00350	.05880	217A	
RESISTOR, FIXED METAL FILM	10.0	30	.03	.12000	.03600	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSFORMER, RF	5.0	30	1.50	.22000	1.65000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
CAPACITOR, T C CER, CC	8.0	30	1.00	.00275	.02200	217A	
CRYSTAL, QUARTZ	4.0	30	1.00	.02000	.08000	217A	

TOTAL FAILURE RATE EQUALS 15.48744 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 64568.4453 HOURS

DESIGN FAILURE RATE GOAL 30.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RCDU-DPU MODEL POSITIONING SET

DATE APR 20,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	68.0	30	1.00	.00512	.34850	217A	
	CAPACITOR, T C CER, CC	2.0	30	1.00	.00275	.00550	217A	
	CAPACITOR, MICA, CM	20.0	30	1.40	.00052	.01449	217A	
	CAPACITOR, SLD TANT, CSR	5.0	30	1.00	.11000	.05500	217A	
	COIL, AUDIO	1.0	30	1.50	.20000	.30000	217A	
	COIL, RF	3.0	30	1.00	.22000	.66000	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	.40000	4.92000	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	6.00	.00350	.11340	217A	
	RESISTOR, FIXED METAL FILM	8.0	30	.03	.12000	.02880	217A	
	TRANSFORMER, RF	2.0	30	1.50	.22000	.66000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	

TOTAL FAILURE RATE EQUALS 12.28813 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 81379.3125 HOURS

DESIGN FAILURE RATE GOAL 21.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU PWR SUP   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.11000	.06600	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	1.00	.06600	.13200	217A	
	COIL, AUDIO	1.0	30	1.50	.20000	.30000	217A	
	DIODE, SILICON, 0-1 WATT	15.0	30	1.50	.25500	5.73750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	6.00	.00350	.03990	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.03	.12000	.00007	217A	
	TRANSFORMER, POWER	1.0	30	1.50	.22000	.33000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	1.50	.25500	1.53000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	.51000	.51000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	1.50	.67000	3.01500	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	1.00	.77000	2.31000	217A	
	CAPACITOR, CER, CK	3.0	30	1.00	.00512	.01537	217A	
	CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	

TOTAL FAILURE RATE EQUALS   14.18224 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   70510.6875 HOURS

DESIGN FAILURE RATE GOAL   46.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPJ WORD CONTROL MODEL POSITIONING SET

DATE APR 20,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	1.00	.00512	.07687	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	5.0	30	6.00	.00350	.01050	217A	

TOTAL FAILURE RATE EQUALS 6.71486 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 148923.4375 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU MSG OUTPUT CTRL MODEL POSITIONING SET

DATE APR 20,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	16.0	30	1.00	.00512	.08200	217A	
CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3 INTEGRATED CIRCUIT, DIGITAL	47.0	30	1.00	.40000	5.64000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	18.0	30	6.00	.00350	.03780	217A	

TOTAL FAILURE RATE EQUALS 7.10728 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 140700.7500 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU DATA ASMBLR & ST MODEL POSITIONING SET

DATE APR 20, '71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	1.00	.00512	.07687	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	46.0	30	1.00	.40000	5.52000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	6.0	30	6.00	.00350	.01260	217A	

TOTAL FAILURE RATE EQUALS 6.95695 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 143741.1250 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU COMMAND DECODER   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	14.0	30	1.00	.00512	.07175	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	20.0	30	6.00	.00350	.04200	217A	
	CAPACITOR, SLD TANT, CSR	1.0	30	1.00	.11000	.01100	217A	

TOTAL FAILURE RATE EQUALS 6.75223 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 148099.2500 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPJ MEMORY MODEL POSITIONING SET

DATE APR 20,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, GLASS, CY	5.0	30	1.00	.00773	.03863	217A	
	CAPACITOR, CER, CK	34.0	30	1.00	.00512	.17425	217A	
	CAPACITOR, SLD TANT, CSR	7.0	30	1.00	.11000	.07700	217A	
	CONNECTOR, 36 PINS	.5	30	1.10	1.22500	.67375	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	59.0	30	1.00	.40000	7.08000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	18.0	30	6.00	.00350	.03780	217A	
S4	RESISTOR, FIXED METAL FILM	4.0	30	.03	.12000	.00014	217A	
	INTEGRATED CIRCUIT, LINEAR	8.0	30	1.00	.40000	3.20000	217A	

TOTAL FAILURE RATE EQUALS 11.28156 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 88640.2500 HOURS

DESIGN FAILURE RATE GOAL 22.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CABLE HARNESS-DPU   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	2.0	30	1.10	.04000	.08800	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
CONNECTOR, 36 PINS	7.0	30	1.10	1.22500	9.43251	217A	
CONNECTOR, 20 PINS	.5	30	1.10	.48600	.26730	217A	

TOTAL FAILURE RATE EGUALS 9.97645 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 100236.0000 HOURS

DESIGN FAILURE RATE GOAL 27.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CONTROL PANEL-DPU   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	COIL, RF	6.0	30	1.00	.22000	1.32000	217A	
	FUSE	1.0	30	1.00	.10000	.10000	217A	
	SWITCH, TOGGLE OR PUSHBUTTON	46.0	30	1.00	.25000	11.50000	217A	
	CAPACITOR, CER, CK	12.0	30	1.00	.00512	.06150	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
	INTEGRATED CIRCUIT, DIGITAL	66.0	30	1.00	.40000	26.39999	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	162.0	30	6.00	.00350	.34020	217A	

TOTAL FAILURE RATE EQUALS 41.06918 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 24349.1562 HOURS

DESIGN FAILURE RATE GOAL 172.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DATA DISPLY UNIT   MODEL POSITIONING SET

DATE MAY 04,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	20.0	30	1.00	.00512	.10250	217A	
COIL, RF	2.0	30	1.00	.22000	.44000	217A	
CONNECTOR, 10 PINS	.5	30	1.10	.22200	.12210	217A	
FUSE	2.0	30	1.00	.10000	.20000	217A	
INTEGRATED CIRCUIT, DIGITAL	31.0	30	1.00	.40000	12.40000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	5.0	30	6.00	.00350	.01050	217A	
RESISTOR, VARIABLE CARBON COMP.	1.0	30	10.00	.10000	1.00000	217A	
SWITCH, TOGGLE OR PUSHBUTTON	2.0	30	1.00	.25000	.50000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	2.0	30	1.00	.51000	1.02000	217A	
CAPACITOR, SLD TANT, CSR	4.0	30	1.00	.11000	.04400	217A	
DIODE, SILICON, 0-1 WATT	6.0	30	1.50	.25500	2.29500	217A	
RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
INDICATOR,HP5082-7000	20.0	30	1.00	.80580	16.11600	SM-188	

TOTAL FAILURE RATE EQUALS 34.25783 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 29190.4062 HOURS

DESIGN FAILURE RATE GOAL 127.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DDJ PWR SUP MODEL POSITIONING SET

DATE APR 20,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.11000	.06600	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	1.00	.06600	.13200	217A	
	COIL, AUDIO	1.0	30	1.50	.20000	.30000	217A	
	DIODE, SILICON, 0-1 WATT	15.0	30	1.50	.25500	5.73750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S+	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	6.00	.00350	.03990	217A	
S+	RESISTOR, FIXED METAL FILM	2.0	30	.03	.12000	.00007	217A	
	TRANSFORMER, POWER	1.0	30	1.50	.22000	.33000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	1.50	.25500	1.53000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	.51000	.51000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	1.50	.67000	3.01500	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	1.00	.77000	2.31000	217A	
	CAPACITOR, CER, CK	3.0	30	1.00	.00512	.01537	217A	
	CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	

TOTAL FAILURE RATE EQUALS 14.18224 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 70510.6875 HOURS

DESIGN FAILURE RATE GOAL 44.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CRYSTAL OSC   MODEL POSITIONING SET

DATE APR 20,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, GLASS, CY	5.0	30	1.00	.00773	.03863	217A	
CAPACITOR, CER, CK	29.0	30	1.00	.00512	.14562	217A	
CAPACITOR, MICA, CM	7.0	30	1.40	.00052	.00507	217A	
CAPACITOR, VAR GLASS, PC	1.0	30	1.00	.02475	.02475	217A	
CAPACITOR, MYLAR, CTM	4.0	30	2.00	.00102	.00820	217A	
CAPACITOR, SLD TANT, CSR	12.0	30	1.00	.11000	.13200	217A	
CAPACITOR, VAR CER, CV	4.0	30	1.00	.02250	.09000	217A	
COIL, AUDIO	2.0	30	1.50	.20000	.60000	217A	
COIL, RF	6.0	30	1.00	.22000	1.32000	217A	
CONNECTOR, RF	4.0	30	1.10	.04000	.17600	217A	
CONNECTOR, 8 PINS	1.0	30	1.10	.18200	.20020	217A	
CRYSTAL, QUARTZ	2.0	30	1.00	.02000	.04000	217A	
DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
DIODE, SILICON, 1-50 WATT	3.0	30	1.00	.43000	1.29000	217A	
FUSE	2.0	30	1.00	.10000	.20000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	1.0	30	6.00	.00350	.00210	217A	
RESISTOR, FIXED METAL FILM	51.0	30	.03	.12000	.18360	217A	
RESISTOR, NON-WW VAR. L. S. ACT.	3.0	30	.10	33.42499	10.02750	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	2.0	30	18.00	.07100	2.55600	RADC	
THERMISTOR	1.0	30	1.00	.30000	.30000	217A	
TRANSFORMER, AUDIO	2.0	30	1.50	.22000	.66000	217A	
TRANSFORMER, POWER	1.0	30	1.50	.22000	.33000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	7.0	30	1.50	.25500	2.67750	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	4.0	30	1.00	.51000	2.04000	217A	
ZENER DIODE, 0-1 WATT	2.0	30	1.00	.77000	1.54000	217A	
THERMOSTAT	1.0	30	1.00	.20000	.20000	217A	

TOTAL FAILURE RATE EQUALS   26.70258 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   37449.5703 HOURS

DESIGN FAILURE RATE GOAL   50.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE OUTSIDE CABLES   MODEL LRPDS SYSTEM

DATE APR 20,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	1.0	30	8.60	.04000	.34400	217A	
CONNECTOR, 8 PINS	2.0	30	4.00	.18200	1.45600	217A	

TOTAL FAILURE RATE EQUALS   1.80000 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   555555.7500 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   TOTAL OF ALL MODULES

DATE APR 20,'71   TEMP 25. C

TOTAL FAILURE RATE EQUALS   580.68921 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   1722.0916 HOURS

APPENDIX F-4.4

WORST CASE

RELIABILITY PREDICTION DATA SHEETS

REFERENCE POSITION SET AN/ASQ-148

ENVIRONMENT: AIRBORNE

TEMPERATURE: +71°C

STRESS LEVELS: DERATING LIMITS EXCEPT
RUBIDIUM STANDARD STRESSES
10% (ASSUMED)

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE POWER CONVERTER MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	3.0	50	5.00	.02425	.36375	217A	
CAPACITOR, SLD TANT, CSR	9.0	50	1.00	.75050	.67545	217A	
CAPACITOR, FOIL TANT, CL	2.0	50	8.00	.16750	2.68000	217A	
COIL, RF	8.0	50	8.60	.22000	15.13600	217A	
DIODE, SILICON, 0-1 WATT	8.0	50	3.50	.41000	11.48000	217A	
DIODE, SILICON, 1-50 WATT	1.0	50	12.00	.90000	10.80000	217A	
FILTER, FEED THRU	9.0	50	1.00	.10940	.98460	217A	
RESISTOR, FIXED CARBON COMPOSITION	8.0	50	10.00	.02650	.21200	217A	
RESISTOR, FIXED METAL FILM	4.0	50	.30	.24850	.29820	217A	
TRANSFORMER, RF	1.0	50	10.00	.22000	2.20000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	50	8.00	.82000	6.56000	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	50	8.00	1.25000	20.00000	217A	
ZENER DIODE, 0-1 WATT	1.0	50	3.00	1.25000	3.75000	217A	
CONNECTOR, 8 PINS	1.0	50	6.00	.18200	1.09200	217A	

TOTAL FAILURE RATE EQUALS 79.51193 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 12576.7266 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RF/IF MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	60	5.00	.00962	.72113	217A	
	CAPACITOR, MICA, CM	2.0	60	15.00	.00036	.01072	217A	
	COIL, RF	1.0	50	8.60	.22000	1.89200	217A	
	CONNECTOR, RF	3.5	50	4.00	.04000	.56000	217A	
	CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	
	INTEGRATED CIRCUIT, LINEAR	5.0	50	1.00	.40000	2.00000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	50	10.00	.02650	.50350	217A	
S3	RESISTOR, NON-WW VAR. L. S. ACT.	1.0	50	2.00	49.12999	9.82600	217A	1
	DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
	TRANSFORMER, RF	2.0	50	10.00	.22000	4.40000	217A	
	CAPACITOR, VAR AIR, CT	2.0	50	1.00	.24700	.49400	217A	

TOTAL FAILURE RATE EQUALS 36.01131 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 27769.0547 HOURS

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE
DUE TO NO FIELD ADJUSTMENTS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER AMPLIFIER   MODEL R/T UNIT

DATE APR 12,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	61.0	30	5.00	.01038	3.35042	217A	
COIL, RF	24.0	30	8.60	.22000	45.40800	217A	
CONNECTOR, RF	6.0	30	4.00	.04000	.96000	217A	
DIODE, HOT CARRIER	3.0	30	3.50	.65000	6.82500	217A	
DIODE, SILICON, 0-1 WATT	8.0	30	3.50	.25500	7.14000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	33.0	30	10.00	.01193	.39353	217A	
TRANSFORMER, RF	10.0	30	10.00	.22000	22.00000	217A	
TRANSISTOR, FIELD EFFECT	9.0	30	8.00	.67000	48.23999	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	9.0	30	8.00	.51000	36.71999	217A	

TOTAL FAILURE RATE EQUALS 173.07690 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 5777.7773 HOURS

DESIGN FAILURE RATE GOAL 97.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE XMTR MODULATOR MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	6.0	60	5.00	.00962	.28845	217A	
CAPACITOR, SLD TANT, CSR	2.0	50	1.00	.75050	.15010	217A	
COIL, RF	2.0	50	8.60	.22000	3.78400	217A	
DIODE, HOT CARRIER	8.0	50	3.50	1.03000	28.83993	217A	
DIODE, SILICON, 0-1 WATT	10.0	50	3.50	.41000	14.35000	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	50	1.00	.40000	.80000	217A	
RELAY, HALF CRYSTAL CAN	3.0	50	50.00	.00310	.46500	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	30.0	50	10.00	.02650	.79500	217A	
TRANSFORMER, RF	4.0	50	10.00	.22000	8.80000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	10.0	50	8.00	.41000	32.79999	217A	
ZENER DIODE, 0-1 WATT	1.0	50	3.00	1.25000	3.75000	217A	

TOTAL FAILURE RATE EQUALS 94.82246 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10546.0234 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE FREQ SYN 1 (XMTR) MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	60	5.00	.00962	1.05765	217A	
CAPACITOR, MICA, CM	16.0	60	15.00	.00036	.08580	217A	
COIL, RF	8.0	50	8.60	.22000	15.13600	217A	
DIODE, HOT CARRIER	12.0	50	3.50	1.03000	43.25998	217A	
DIODE, SILICON, 0-1 WATT	5.0	50	3.50	.41000	7.17500	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	50	1.00	.40000	.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	57.0	50	10.00	.02650	1.51050	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	50	8.00	.41000	19.67999	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	50	8.00	1.25000	20.00000	217A	
TRANSFORMER, RF	4.0	50	10.00	.22000	8.80000	217A	
RESISTOR,VARIABLE,10-TURN	1.0	50	2.00	2.03900	4.07800	SM-188	

TOTAL FAILURE RATE EQUALS 121.58287 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 8224.8398 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE FREQ SYN 2 (REC) MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	60	5.00	.00962	1.05765	217A	
CAPACITOR, MICA, CM	16.0	60	15.00	.00036	.08580	217A	
COIL, RF	8.0	50	8.60	.22000	15.13600	217A	
DIODE, HOT CARRIER	12.0	50	3.50	1.03000	43.25998	217A	
DIODE, SILICON, 0-1 WATT	5.0	50	3.50	.41000	7.17500	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	50	1.00	.40000	.80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	57.0	50	10.00	.02650	1.51050	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	50	8.00	.41000	19.67999	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	50	8.00	1.25000	20.00000	217A	
TRANSFORMER, RF	4.0	50	10.00	.22000	8.80000	217A	
RESISTOR, VARIABLE, 10-TURN	1.0	50	2.00	2.03900	4.07800	SM-188	
CONNECTOR, RF	3.0	50	4.00	.04000	.48000	217A	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 123.09186 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 8124.0117 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CARRIER IG/VCO MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	2.0	50	1.00	.24700	.49400	217A	
	CAPACITOR, CER, CK	72.0	60	5.00	.00962	3.46140	217A	
	CAPACITOR, MICA, CM	14.0	60	15.00	.00036	.07507	217A	
	COIL, RF	6.0	50	8.60	.22000	11.35200	217A	
	CONNECTOR, RF	3.0	50	4.00	.04000	.48000	217A	
	CONNECTOR, 8 PINS	.5	50	6.00	.18200	.54600	217A	
	DIODE, SILICON, 0-1 WATT	5.0	50	3.50	.41000	7.17500	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	50	1.00	.40000	1.20000	217A	
	INTEGRATED CIRCUIT, LINEAR	19.0	50	1.00	.40000	7.60000	217A	
S+	RESISTOR, FIXED CARBON COMPOSITION	80.0	50	10.00	.02650	2.12000	217A	
	RESISTOR, FIXED METAL FILM	27.0	50	.30	.24850	2.01285	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	3.0	50	18.00	.17075	9.22050	RADC	
	TRANSISTOR, SILICON NPN, 0-1 WATT	5.0	50	8.00	.41000	16.39999	217A	
	ZENER DIODE, 0-1 WATT	3.0	50	3.00	1.25000	11.25000	217A	
	DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
	TRANSFORMER, RF	2.0	50	10.00	.22000	4.40000	217A	
	CRYSTAL, QUARTZ	3.0	50	1.00	.02000	.06000	217A	
	CAPACITOR, T C CER, CC	4.0	50	5.00	.06200	1.24000	217A	
	CAPACITOR, VAR GLASS, PC	1.0	50	20.00	.24250	4.85000	217A	
	CAPACITOR, VAR CER, CV	1.0	50	1.00	.24700	.24700	217A	
S+	RESISTOR, FIXED METAL FILM	2.0	50	.30	.24850	.00149	217A	

TOTAL FAILURE RATE EQUALS 98.60519 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10141.4531 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CODE DETECTOR   MODEL R/T UNIT

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	46.0	60	5.00	.00962	2.21145	217A	
CAPACITOR, MICA, CM	4.0	60	15.00	.00036	.02145	217A	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	
DIODE, SILICON, 0-1 WATT	7.0	50	3.50	.41000	10.04500	217A	
INTEGRATED CIRCUIT, DIGITAL	3.0	50	1.00	.40000	1.20000	217A	
INTEGRATED CIRCUIT, LINEAR	19.0	50	1.00	.40000	7.60000	217A	
RESISTOR, FIXED METAL FILM	28.0	50	.30	.24850	2.08740	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	.17075	3.07350	RADC	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	

TOTAL FAILURE RATE EQUALS   30.54776 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   32735.6211 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CACU (DIGITAL)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	30.0	60	5.00	.00962	1.44225	217A	
	INTEGRATED CIRCUIT, DIGITAL	71.0	50	1.00	.40000	28.39999	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S.	RESISTOR, FIXED CARBON COMPOSITION	54.0	50	10.00	.02650	1.43100	217A	
	CAPACITOR, MICA, CM	6.0	60	15.00	.00036	.03218	217A	
	COIL, RF	3.0	50	8.60	.22000	5.67600	217A	
	CONNECTOR, RF	6.0	50	4.00	.04000	.96000	217A	
	CONNECTOR, 36 PINS	.5	50	6.00	1.22500	3.67500	217A	

TOTAL FAILURE RATE EQUALS 41.77138 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 23939.8359 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK IQ DETECTOR MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	50	1.00	.24700	.24700	217A	
CAPACITOR, CER, CK	36.0	50	5.00	.02425	4.36500	217A	
CAPACITOR, MICA, CM	10.0	50	15.00	.00537	.80550	217A	
COIL, RF	6.0	50	8.60	.22000	11.35200	217A	
CONNECTOR, RF	3.0	50	4.00	.04000	.48000	217A	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	
DIODE, SILICON, 0-1 WATT	2.0	50	3.50	.41000	2.87000	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	50	1.00	.40000	4.80000	217A	
S+ RESISTOR, FIXED CARBON COMPOSITION	48.0	50	10.00	.02650	1.27200	217A	
RESISTOR, FIXED METAL FILM	13.0	50	.30	.24850	.96915	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	.17075	3.07350	RADC	
TRANSFORMER, RF	6.0	50	10.00	.22000	13.20000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	2.0	50	8.00	.41000	6.56000	217A	
ZENER DIODE, 0-1 WATT	1.0	50	3.00	1.25000	3.75000	217A	
DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
CAPACITOR, T C CER, CC	4.0	50	5.00	.06200	1.24000	217A	
CRYSTAL, QUARTZ	2.0	50	1.00	.02000	.04000	217A	

TOTAL FAILURE RATE EQUALS 70.47304 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 14189.8203 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK PHASE CONTROL MODEL R/T UNIT

DATE APR 21,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	38.0	60	5.00	.00962	1.82685	217A	
	CAPACITOR, MICA, CM	4.0	60	15.00	.00036	.02145	217A	
	COIL, RF	5.0	50	8.60	.22000	9.46000	217A	
	DIODE, SILICON, 0-1 WATT	1.0	50	3.50	.41000	1.43500	217A	
	INTEGRATED CIRCUIT, DIGITAL	4.0	50	1.00	.40000	1.60000	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	50	1.00	.40000	4.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	28.0	50	10.00	.02650	.74200	217A	
	RESISTOR, FIXED METAL FILM	10.0	50	.30	.24850	.74550	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	.17075	3.07350	RADC	
	TRANSFORMER, RF	5.0	50	10.00	.22000	11.00000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	
	DIODE, HOT CARRIER	4.0	50	3.50	1.03000	14.42000	217A	
	CAPACITOR, T C CER, CC	8.0	50	5.00	.06200	2.48000	217A	
	CRYSTAL, QUARTZ	4.0	50	1.00	.02000	.08000	217A	

TOTAL FAILURE RATE EQUALS 54.96423 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 18193.6484 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RTU CABLE HARNESS MODEL POSITIONING SET

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	18.0	50	4.00	.04000	2.88000	217A	
CONNECTOR, 8 PINS	2.0	50	6.00	.18200	2.18400	217A	
CONNECTOR, 15 PINS	3.0	50	6.00	.34300	6.17400	217A	
CONNECTOR, 36 PINS	1.5	50	6.00	1.22500	11.02500	217A	

TOTAL FAILURE RATE EQUALS 22.26300 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 44917.5742 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RCDU-DPU   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	68.0	60	5.00	.00962	3.26910	217A	
CAPACITOR, T C CER, CC	2.0	50	5.00	.06200	.62000	217A	
CAPACITOR, MICA, CM	20.0	60	15.00	.00036	.10725	217A	
CAPACITOR, SLD TANT, CSR	5.0	50	1.00	.75050	.37525	217A	
COIL, AUDIO	1.0	50	10.00	.22750	2.27500	217A	
COIL, RF	3.0	50	8.60	.22000	5.67600	217A	
INTEGRATED CIRCUIT, DIGITAL	41.0	50	1.00	.40000	16.39999	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	50	1.00	.40000	4.80000	217A	
S* RESISTOR, FIXED CARBON COMPOSITION	54.0	50	10.00	.02650	1.43100	217A	
RESISTOR, FIXED METAL FILM	8.0	50	.30	.24850	.59640	217A	
TRANSFORMER, RF	2.0	50	10.00	.22000	4.40000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	50	8.00	.41000	3.28000	217A	

TOTAL FAILURE RATE EQUALS   43.22995 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   23132.1094 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPJ PWR SUP   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	50	1.00	.75050	.45030	217A	
	CAPACITOR, FOIL TANT, CL	2.0	50	8.00	.16750	2.68000	217A	
	COIL, AUDIO	1.0	50	10.00	.22750	2.27500	217A	
	DIODE, SILICON, 0-1 WATT	15.0	50	3.50	.41000	21.52499	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S*	RESISTOR, FIXED CARBON COMPOSITION	19.0	50	10.00	.02650	.50350	217A	
S*	RESISTOR, FIXED METAL FILM	2.0	50	.30	.24850	.00149	217A	
	TRANSFORMER, POWER	1.0	50	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	50	8.00	.41000	13.12000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	50	8.00	.82000	6.56000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	50	8.00	1.25000	30.00000	217A	
	ZENER DIODE, 0-1 WATT	3.0	50	3.00	1.25000	11.25000	217A	
	CAPACITOR, CER, CK	3.0	60	5.00	.00962	.14423	217A	
	CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS   91.89345 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   10882.1680 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU WORD CONTROL   MODEL POSITIONING SET

DATE APR 21, '71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	60	5.00	.00962	.72113	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	44.0	50	1.00	.40000	17.59999	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	5.0	50	10.00	.02650	.13250	217A	

TOTAL FAILURE RATE EQUALS 25.80360 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 38754.2734 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU MSG OUTPUT CTRL MODEL POSITIONING SET

DATE APR 21,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	16.0	60	5.00	.00962	.76920	217A	
	CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
	INTEGRATED CIRCUIT, DIGITAL	47.0	50	1.00	.40000	18.79999	217A	
S+	RESISTOR, FIXED CARBON COMPOSITION	18.0	50	10.00	.02650	.47700	217A	

TOTAL FAILURE RATE EQUALS 27.39618 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 36501.4375 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPJ DATA ASMBLR & ST   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	60	5.00	.00962	.72113	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
INTEGRATED CIRCUIT, DIGITAL	46.0	50	1.00	.40000	18.39999	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	6.0	50	10.00	.02650	.15900	217A	

TOTAL FAILURE RATE EQUALS   26.63011 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   37551.4727 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPJ COMMAND DECODER   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	14.0	60	5.00	.00962	.67305	217A	
	CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
	INTEGRATED CIRCUIT, DIGITAL	44.0	50	1.00	.40000	17.59999	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	20.0	50	10.00	.02650	.53000	217A	
	CAPACITOR, SLD TANT, CSR	1.0	50	1.00	.75050	.07505	217A	

TOTAL FAILURE RATE EQUALS   26.22807 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   38127.0859 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CABLE HARNESS-DPJ   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	2.0	50	4.00	.04000	.32000	217A	
CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	
CONNECTOR, 36 PINS	7.0	50	6.00	1.22500	51.45001	217A	
CONNECTOR, 20 PINS	.5	50	6.00	.48600	1.45800	217A	

TOTAL FAILURE RATE EQUALS 54.25700 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 18430.7969 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE MEMORY PWR SUP MODEL AIRBORNE PSS SET

DATE APR 21,'71 TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	50	1.00	.75050	.45030	217A	
	CAPACITOR, FOIL TANT, CL	2.0	50	8.00	.16750	2.68000	217A	
	COIL, AUDIO	1.0	50	10.00	.22750	2.27500	217A	
	DIODE, SILICON, 0-1 WATT	15.0	50	3.50	.41000	21.52499	217A	
	RELAY, HALF CRYSTAL CAN	1.0	50	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	50	10.00	.02650	.50350	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	50	.30	.24850	.00149	217A	
	TRANSFORMER, POWER	1.0	50	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	50	8.00	.41000	13.12000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	50	8.00	.82000	6.56000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	50	8.00	1.25000	30.00000	217A	
	ZENER DIODE, 0-1 WATT	3.0	50	3.00	1.25000	11.25000	217A	
	CAPACITOR, CER, CK	3.0	50	5.00	.02425	.36375	217A	
	CONNECTOR, 15 PINS	.5	50	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 92.11298 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10856.2305 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE AIRBORNE MEMORY   MODEL AIRBORNE PBS SET

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	5.0	50	5.00	.02425	.60625	217A	
CAPACITOR, SLD TANT, CSR	17.0	50	1.00	.75050	1.27585	217A	
CONNECTOR, 10 PINS	9.0	50	6.00	.22200	11.98800	217A	
CONNECTOR, 20 PINS	15.0	50	6.00	.48600	43.73999	217A	
DIODE, SILICON, 0-1 WATT	50.0	50	3.50	.41000	71.75000	217A	
INTEGRATED CIRCUIT, DIGITAL	41.0	50	1.00	.40000	16.39999	217A	
INTEGRATED CIRCUIT, LINEAR	41.0	50	1.00	.40000	16.39999	217A	
RESISTOR, FIXED METAL FILM	92.0	50	.30	.24850	6.85859	217A	
RESISTOR, FIXED WIRE WOUND	21.0	50	3.00	1.25350	78.97043	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	14.0	50	8.00	.41000	45.92000	217A	
ZENER DIODE, 0-1 WATT	2.0	50	3.00	1.25000	7.50000	217A	
CORES, FERRITE	3) 201.0	50	1.00	.00002	.49922	217A	
CORES, FERRITE	99999.0	50	1.00	.00002	1.59998	217A	

TOTAL FAILURE RATE EQUALS   303.50781 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   3294.8079 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FILTER , AIRBORNE   MODEL POSITION SET,AIR

DATE APR 21,'71   TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	5.0	50	1.00	.24700	1.23500	217A	

TOTAL FAILURE RATE EQUALS 1.23500 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 809716.8125 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CONTROL & MONITOR MODEL POSITION SET, AIR

DATE APR 21, '71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
COIL, RF	11.0	50	8.60	.22000	20.81200	217A	
CONNECTOR, 8 PINS	1.0	50	6.00	.18200	1.09200	217A	
CONNECTOR, 36 PINS	1.0	50	6.00	1.22500	7.35000	217A	
SWITCH, TOGGLE OR PUSHBUTTON	7.0	50	18.00	.25000	31.50000	217A	

TOTAL FAILURE RATE EQUALS 60.75398 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 16459.8242 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RUBIDIUM FREQ STD   MODEL AIRBORNE PBS SET

DATE APR 21,'71   TEMP 71. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, ALUM ELECT, CE	3.0	10	.60	.37650	.67770	217A	
	CAPACITOR, GLASS, CY	4.0	10	18.00	.02965	2.13480	217A	
	CAPACITOR, CER, CK	52.0	10	5.00	.00602	1.56650	217A	
	CAPACITOR, MICA, CM	74.0	10	15.00	.00032	.35131	217A	
	CAPACITOR, FD-THRU	12.0	10	5.00	.02060	1.23600	217A	
	CAPACITOR, MYLAR, CTM	13.0	10	10.00	.00121	.15730	217A	
	CAPACITOR, SLD TANT, CSR	82.0	10	1.00	.13300	1.09060	217A	
	CAPACITOR, VAR CER, CV	3.0	10	1.00	.01185	.03555	217A	
	COIL, RF	49.0	10	8.60	.22000	92.70798	217A	
	CONNECTOR, RF	36.0	10	4.00	.04000	5.76000	217A	
	CONNECTOR, 8 PINS	2.0	10	6.00	.18200	2.18400	217A	
	CONNECTOR, 20 PINS	3.0	10	6.00	.48600	8.74800	217A	
	CRYSTAL, QUARTZ	3.0	10	1.00	.02000	.06000	217A	
	DIODE, GERMANIUM, 0-1 WATT	2.0	10	3.50	1.40000	9.80000	217A	
	DIODE, SILICON, 0-1 WATT	34.0	10	3.50	.14000	16.65999	217A	
	DIODE, SILICON, 1-50 WATT	8.0	10	12.00	.16000	15.36000	217A	
	FILTER, FEED THRU	1.0	10	1.00	.02060	.02060	217A	
	FUSE	3.0	10	1.00	.10000	.30000	217A	
	INTEGRATED CIRCUIT, DIGITAL	16.0	10	1.00	.40000	6.40000	217A	
	INTEGRATED CIRCUIT, LINEAR	10.0	10	1.00	.40000	4.00000	217A	
	METER	1.0	10	1.00	.50000	.50000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	10	50.00	.00310	.15500	217A	
S*	RESISTOR, FIXED CARBON COMPOSITION	295.0	10	10.00	.00542	1.60037	217A	
S*	RESISTOR, FIXED METAL FILM	47.0	10	.30	.20200	.02848	217A	
	RESISTOR, FIXED WIRE WOUND	2.0	10	3.00	1.14150	6.84900	217A	
	RESISTOR, NON-WW VAR. L. S. ACT.	10.0	10	2.00	43.52499	870.49976	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	5.0	10	18.00	.09785	8.80650	RADC	
	SWITCH, TOGGLE OR PUSHBUTTON	16.0	10	18.00	.25000	72.00000	217A	
	THERMISTOR	2.0	10	1.00	.30000	.60000	217A	
	TRANSFORMER, POWER	1.0	10	10.00	.22000	2.20000	217A	
	TRANSFORMER, RF	10.0	10	10.00	.22000	22.00000	217A	

TRANSISTOR, FIELD EFFECT	3.0	10	8.00	.30500	7.32000	217A
TRANSISTOR, GERMANIUM PNP, 1-50 WATT	2.0	10	8.00	1.10000	17.60001	217A
TRANSISTOR, SILICON NPN, 0-1 WATT	62.0	10	8.00	.14000	69.43999	217A
TRANSISTOR, SILICON NPN, 1-50 WATT	10.0	10	8.00	.28000	22.39999	217A
TRANSISTOR, SILICON PNP, 0-1 WATT	11.0	10	8.00	.30500	26.84000	217A
TRANSISTOR, SILICON PNP, 1-50 WATT	2.0	10	8.00	.61000	9.76000	217A
VARICAP	4.0	10	3.50	.14000	1.96000	217A
ZENER DIODE, 0-1 WATT	8.0	10	3.00	.42000	10.08000	217A
ZENER DIODE, 1-50 WATT	1.0	10	3.00	.42000	1.26000	217A

TOTAL FAILURE RATE EQUALS 1321.14771 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 756.9175 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE OUTSIDE CABLES MODEL LRPDS SYSTEM

DATE APR 21,'71 TEMP 71. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	1.0	50	4.00	.04000	.16000	217A	
CONNECTOR, 8 PINS	2.0	50	6.00	.18200	2.18400	217A	

TOTAL FAILURE RATE EQUALS 2.34400 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 426621.3125 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   TOTAL OF ALL MODULES

DATE APR 21,'71   TEMP   71. C

TOTAL FAILURE RATE EQUALS   3104.39087 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   322.1243 HOURS

APPENDIX F-4.5

TYPICAL OPERATION

RELIABILITY PREDICTION DATA SHEETS

REFERENCE POSITION SET AN/ASQ-148

ENVIRONMENT: AIRBORNE

TEMPERATURE: +50°C

STRESS LEVELS: 30% (ASSUMED) EXCEPT
RUBIDIUM STANDARD STRESSES
AT 10% (ASSUMED)

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE POWER CONVERTER MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	3.0	30	5.00	.00640	.09600	217A	
	CAPACITOR, SLD TANT, CSR	9.0	30	1.00	.17000	.15300	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	8.00	.03650	1.38400	217A	
S3	COIL, RF	8.0	30	8.60	.22000	4.54080	217A	
	DIODE, SILICON, 0-1 WATT	8.0	30	3.50	.25500	7.14000	217A	
	DIODE, SILICON, 1-50 WATT	1.0	30	12.00	.43000	5.16000	217A	
	FILTER, FEED THRU	9.0	30	1.00	.02400	.21600	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	8.0	30	10.00	.00400	.03200	217A	
	RESISTOR, FIXED METAL FILM	4.0	30	.30	.17000	.20400	217A	
	TRANSFORMER, RF	1.0	30	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	8.00	.51000	4.08000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	8.00	.67000	10.72000	217A	
	ZENER DIODE, 0-1 WATT	1.0	30	3.00	.77000	2.31000	217A	
	CONNECTOR, 8 PINS	1.0	30	6.00	.18200	1.09200	217A	

TOTAL FAILURE RATE EQUALS 41.36771 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 24173.4453 HOURS

DESIGN FAILURE RATE GOAL 44.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RF/IF   MODEL R/T UNIT

DATE APR 21, '71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	5.00	.00640	.48000	217A	
	CAPACITOR, MICA, CM	2.0	30	15.00	.00071	.02145	217A	
	COIL, RF	1.0	30	8.60	.22000	1.89200	217A	
	CONNECTOR, RF	3.5	30	4.00	.04000	.56000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
	INTEGRATED CIRCUIT, LINEAR	5.0	30	1.00	.40000	2.00000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	10.00	.00400	.07600	217A	
S3	RESISTOR, NON-WW VAR. L. S. ACT.	1.0	30	2.00	39.30000	7.86000	217A	1
S3	DIODE, HOT CARRIER	4.0	30	3.50	.65000	2.73000	217A	
S3	TRANSFORMER, RF	2.0	30	10.00	.22000	1.32000	217A	
	CAPACITOR, VAR AIR, CT	2.0	30	1.00	.03500	.07000	217A	

TOTAL FAILURE RATE EQUALS 18.19342 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 54964.9219 HOURS

DESIGN FAILURE RATE GOAL 19.00000 FAILURES PER MILLION HOURS

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE
DUE TO NO FIELD ADJUSTMENTS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE POWER AMPLIFIER MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	61.0	30	5.00	.00640	1.95200	217A	
S3	COIL, RF	24.0	30	8.60	.22000	13.62241	217A	
	CONNECTOR, RF	1.5	30	4.00	.04000	.24000	217A	
	DIODE, HOT CARRIER	3.0	30	3.50	.65000	6.82500	217A	
	DIODE, SILICON, 0-1 WATT	8.0	30	3.50	.25500	7.14000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	33.0	30	10.00	.00400	.13200	217A	
	TRANSFORMER, RF	10.0	30	10.00	.22000	22.00000	217A	
S3	TRANSISTOR, FIELD EFFECT	9.0	30	8.00	.67000	14.47200	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
S3	TRANSISTOR, SILICON NPN, 1-50 WATT	9.0	30	8.00	.51000	11.01601	217A	
	CONNECTOR, 36 PINS	.5	30	6.00	1.22500	3.67500	217A	

TOTAL FAILURE RATE EQUALS 83.11436 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 12031.6133 HOURS

DESIGN FAILURE RATE GOAL 95.00000 FAILURES PER MILLION HOURS

AD-A047 145 MOTOROLA INC SCOTTSDALE ARIZ GOVERNMENT ELECTRONICS DIV F/G 17/3
LRPDS INTERIM TECHNICAL REPORT. APPENDICES,(U)
JUN 71 S ATTWOOD DAAK02-71-C-0022

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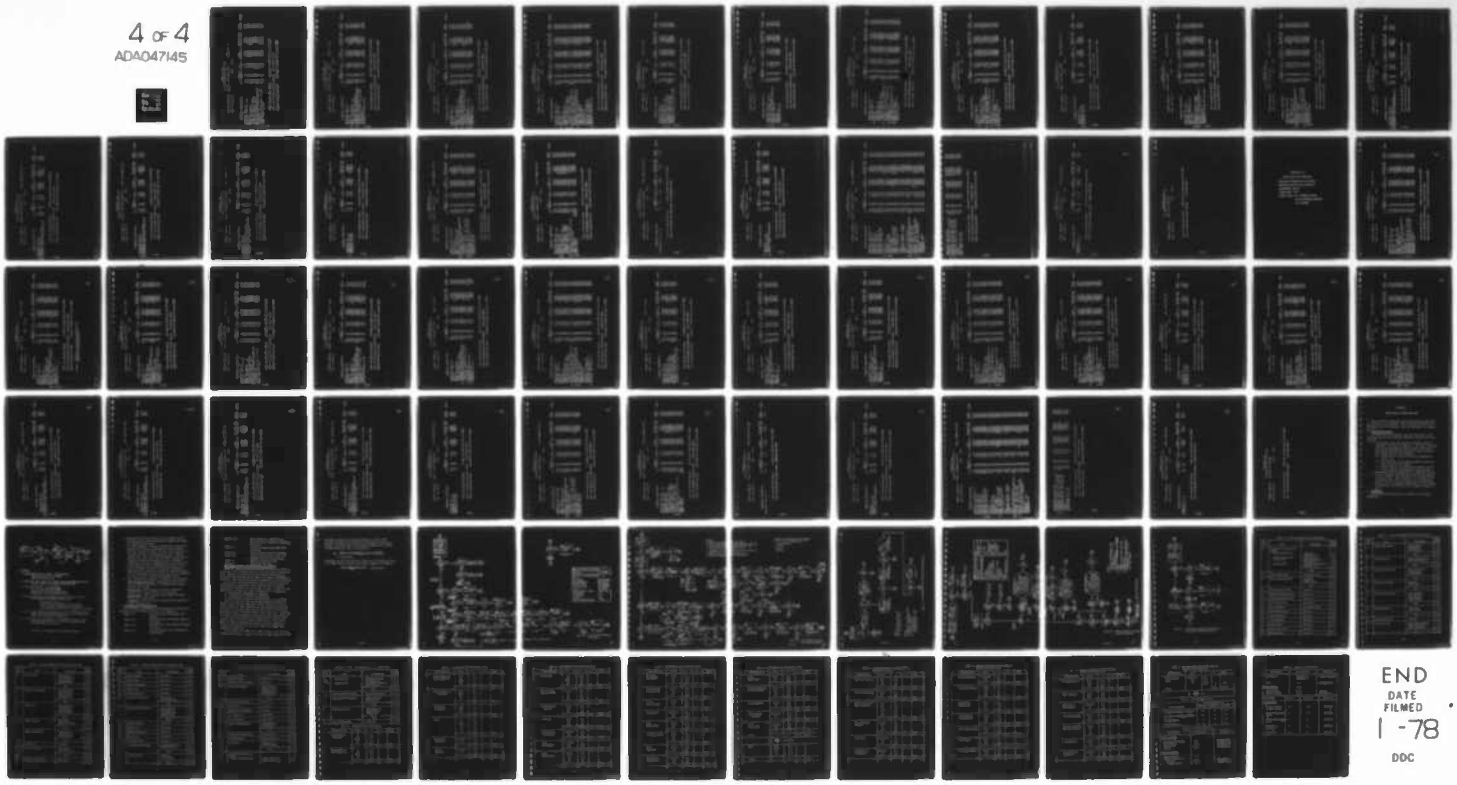

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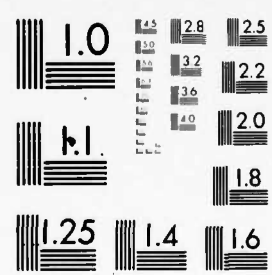

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MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE XMTR MODULATOR MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	6.0	30	5.00	.00640	.19200	217A	
	CAPACITOR, SLD TANT, CSR	2.0	30	1.00	.17000	.03400	217A	
	COIL, RF	2.0	30	8.60	.22000	3.78400	217A	
	DIODE, HOT CARRIER	8.0	30	3.50	.65000	18.20000	217A	
	DIODE, SILICON, 0-1 WATT	10.0	30	3.50	.25500	8.92500	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
	RELAY, HALF CRYSTAL CAN	3.0	30	50.00	.00310	.46500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	30.0	30	10.00	.00400	.12000	217A	
	TRANSFORMER, RF	4.0	30	10.00	.22000	8.80000	217A	
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	10.0	30	8.00	.25500	6.12000	217A	
	ZENER DIODE, 0-1 WATT	1.0	30	3.00	.77000	2.31000	217A	

TOTAL FAILURE RATE EQUALS 49.74994 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 20100.5234 HOURS

DESIGN FAILURE RATE GOAL 52.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREG SYN 1 (XMTR)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	22.0	30	5.00	.00640	.70400	217A	
	CAPACITOR, MICA, CM	16.0	30	15.00	.00071	.17160	217A	
	COIL, RF	8.0	30	8.60	.22000	15.13600	217A	
S3	DIODE, HOT CARRIER	12.0	30	3.50	.65000	8.19000	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	57.0	30	10.00	.00400	.22800	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	8.00	.25500	12.24000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	8.00	.67000	10.72000	217A	
	TRANSFORMER, RF	4.0	30	10.00	.22000	8.80000	217A	
	RESISTOR, VARIABLE, 10-TURN	1.0	30	2.00	1.51000	3.02000	SM-188	

TOTAL FAILURE RATE EQUALS   64.47203 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   15510.6016 HOURS

DESIGN FAILURE RATE GOAL   66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE FREQ SYN 2 (REC) MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	22.0	30	5.00	.00640	.70400	217A	
	CAPACITOR, MICA, CM	16.0	30	15.00	.00071	.17160	217A	
	COIL, RF	8.0	30	5.60	.22000	15.13600	217A	
S3	DIODE, HOT CARRIER	12.0	30	3.50	.65000	8.19000	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	57.0	30	10.00	.00400	.22800	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	8.00	.25500	12.24000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	8.00	.67000	10.72000	217A	
	TRANSFORMER, RF	4.0	30	10.00	.22000	8.80000	217A	
	RESISTOR, VARIABLE, 10-TURN	1.0	30	2.00	1.51000	3.02000	SM-188	
	CONNECTOR, RF	3.0	30	4.00	.04000	.48000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 65.98102 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 15155.8711 HOURS

DESIGN FAILURE RATE GOAL 66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CARRIER IQ/VCO MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	2.0	30	1.00	.03500	.07000	217A	
	CAPACITOR, CER, CK	72.0	30	5.00	.00640	2.30400	217A	
	CAPACITOR, MICA, CM	14.0	30	15.00	.00071	.15015	217A	
S3	COIL, RF	6.0	30	8.60	.22000	3.40560	217A	
	CONNECTOR, RF	3.0	30	4.00	.04000	.48000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	3.50	.25500	4.46250	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
	INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	7.60000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	80.0	30	10.00	.00400	.32000	217A	
	RESISTOR, FIXED METAL FILM	27.0	30	.30	.17000	1.37700	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	3.0	30	18.00	.09600	5.18400	RADC	
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	5.0	30	8.00	.25500	3.06000	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	3.00	.77000	6.93000	217A	
	DIODE, HOT CARRIER	4.0	30	3.50	.65000	9.10000	217A	
	TRANSFORMER, RF	2.0	30	10.00	.22000	4.40000	217A	
	CRYSTAL, QUARTZ	3.0	30	1.00	.02000	.06000	217A	
	CAPACITOR, T C CER, CC	4.0	30	5.00	.00625	.12500	217A	
	CAPACITOR, VAR GLASS, PC	1.0	30	20.00	.05850	1.17000	217A	
	CAPACITOR, VAR CER, CV	1.0	30	1.00	.03500	.03500	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.30	.17000	.00102	217A	

TOTAL FAILURE RATE EQUALS 52.46315 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 19060.9961 HOURS

DESIGN FAILURE RATE GOAL 54.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CODE DETECTOR MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	46.0	30	5.00	.00640	1.47200	217A	
	CAPACITOR, MICA, CM	4.0	30	15.00	.00071	.04290	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
S3	DIODE, SILICON, 0-1 WATT	7.0	30	3.50	.25500	1.87425	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
S3	INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	2.28000	217A	
	RESISTOR, FIXED METAL FILM	28.0	30	.30	.17000	1.42800	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.09600	1.72800	RADC	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	

TOTAL FAILURE RATE EQUALS 13.09411 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 76370.1875 HOURS

DESIGN FAILURE RATE GOAL 16.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CACU (DIGITAL)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	30.0	30	5.00	.00640	.96000	217A	
S*	INTEGRATED CIRCUIT, DIGITAL	71.0	30	1.00	.04000	2.84000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S*	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	10.00	.00400	.21600	217A	
	CAPACITOR, MICA, CM	6.0	30	15.00	.00071	.06435	217A	
	COIL, RF	3.0	30	8.60	.22000	5.67600	217A	
	CONNECTOR, RF	6.0	30	4.00	.04000	.96000	217A	
	CONNECTOR, 36 PINS	.5	30	6.00	1.22500	3.67500	217A	

TOTAL FAILURE RATE EQUALS   14.54630 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   68745.9375 HOURS

DESIGN FAILURE RATE GOAL   20.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK IG DETECTOR MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	1.0	30	1.00	.03500	.03500	217A	
	CAPACITOR, CER, CK	36.0	30	5.00	.00640	1.15200	217A	
	CAPACITOR, MICA, CM	10.0	30	15.00	.00071	.10725	217A	
S3	COIL, RF	6.0	30	8.60	.22000	3.40560	217A	
	CONNECTOR, RF	3.0	30	4.00	.04000	.48000	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
	DIODE, SILICON, 0-1 WATT	2.0	30	3.50	.25500	1.78500	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	48.0	30	1.00	.00400	.19200	217A	
	RESISTOR, FIXED METAL FILM	13.0	30	.30	.17000	.66300	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.09600	1.72800	RADC	
S3	TRANSFORMER, RF	6.0	30	10.00	.22000	3.96000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	2.0	30	8.00	.25500	4.08000	217A	
	ZENER DIODE, 0-1 WATT	1.0	30	3.00	.77000	2.31000	217A	
	DIODE, HOT CARRIER	4.0	30	3.50	.65000	9.10000	217A	
	CAPACITOR, T C CER, CC	4.0	30	5.00	.00625	.12500	217A	
	CRYSTAL, QUARTZ	2.0	30	1.00	.02000	.04000	217A	

TOTAL FAILURE RATE EQUALS 34.99174 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 28578.1680 HOURS

DESIGN FAILURE RATE GOAL 36.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK PHASE CONTROL MODEL R/T UNIT

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	38.0	30	5.00	.00640	1.21600	217A	
	CAPACITOR, MICA, CM	4.0	30	15.00	.00071	.04290	217A	
S3	COIL, RF	5.0	30	8.60	.22000	2.83800	217A	
	DIODE, SILICON, 0-1 WATT	1.0	30	3.50	.25500	.89250	217A	
	INTEGRATED CIRCUIT, DIGITAL	4.0	30	1.00	.40000	1.60000	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	28.0	30	10.00	.00400	.11200	217A	
	RESISTOR, FIXED METAL FILM	10.0	30	.30	.17000	.51000	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.09600	1.72800	RADC	
S3	TRANSFORMER, RF	5.0	30	10.00	.22000	3.30000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	
	DIODE, HOT CARRIER	4.0	30	3.50	.65000	9.10000	217A	
	CAPACITOR, T C CER, CC	8.0	30	5.00	.00625	.25000	217A	
	CRYSTAL, QUARTZ	4.0	30	1.00	.02000	.08000	217A	

TOTAL FAILURE RATE EQUALS 28.50932 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 35075.2422 HOURS

DESIGN FAILURE RATE GOAL 30.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RTJ CABLE HARNESS MODEL POSITIONING SET

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CONNECTOR, RF	18.0	30	4.00	.04000	2.88000	217A	
	CONNECTOR, 8 PINS	2.0	30	6.00	.18200	2.18400	217A	
S3	CONNECTOR, 15 PINS	3.0	30	6.00	.34300	1.85220	217A	
S3	CONNECTOR, 36 PINS	1.5	30	6.00	1.22500	3.30750	217A	

TOTAL FAILURE RATE EQUALS 10.22370 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 97811.9375 HOURS

DESIGN FAILURE RATE GOAL 12.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RCDU-DPU MODEL POSITIONING SET

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	68.0	30	5.00	.00640	2.17600	217A	
	CAPACITOR, T C CER, CC	2.0	30	5.00	.00625	.06250	217A	
	CAPACITOR, MICA, CM	20.0	30	15.00	.00071	.21450	217A	
	CAPACITOR, SLD TANT, CSR	5.0	30	1.00	.17000	.08500	217A	
	COIL, AUDIO	1.0	30	10.00	.20000	2.00000	217A	
S3	COIL, RF	3.0	30	8.60	.22000	1.70280	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	.40000	4.92000	217A	
S3	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	1.44000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	10.00	.00400	.21600	217A	
	RESISTOR, FIXED METAL FILM	8.0	30	.30	.17000	.40800	217A	
	TRANSFORMER, RF	2.0	30	10.00	.22000	4.40000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	8.00	.25500	2.04000	217A	

TOTAL FAILURE RATE EQUALS 19.66473 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 50852.4531 HOURS

DESIGN FAILURE RATE GOAL 21.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU PWR SUP   MODEL POSITIONING SET

DATE APR 21, '71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.17000	.10200	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	8.00	.08650	1.38400	217A	
	COIL, AUDIO	1.0	30	10.00	.20000	2.00000	217A	
	DIODE, SILICON, 0-1 WATT	15.0	30	3.50	.25500	13.38750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	10.00	.00400	.07600	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.30	.17000	.00102	217A	
	TRANSFORMER, POWER	1.0	30	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	8.00	.25500	8.16000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	8.00	.51000	4.08000	217A	
S3	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	8.00	.67000	4.82400	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	3.00	.77000	6.93000	217A	
	CAPACITOR, CER, CK	3.0	30	5.00	.00640	.09600	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS   44.42442 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   22510.1367 HOURS

DESIGN FAILURE RATE GOAL   46.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU WORD CONTROL MODEL POSITIONING SET

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	5.00	.00640	.48000	217A	
S3	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	5.0	30	10.00	.00400	.02000	217A	

TOTAL FAILURE RATE EQUALS 7.98499 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 125235.0000 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU MSG OUTPUT CTRL   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	16.0	30	5.00	.00640	.51200	217A	
S3	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	47.0	30	1.00	.40000	5.64000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	18.0	30	10.00	.00400	.07200	217A	

TOTAL FAILURE RATE EGUALS   8.42899 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   118635.1875 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU DATA ASMBLR & ST   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	5.00	.00640	.48000	217A	
S3	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	46.0	30	1.00	.40000	5.52000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	6.0	30	10.00	.00400	.02400	217A	

TOTAL FAILURE RATE EQUALS   8.22899 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   121521.6250 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPU COMMAND DECODER   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	14.0	30	5.00	.00640	.44800	217A	
S3	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	2.20500	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	20.0	30	10.00	.00400	.08000	217A	
	CAPACITOR, SLD TANT, CSR	1.0	30	1.00	.17000	.01700	217A	

TOTAL FAILURE RATE EQUALS   8.02997 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   124533.4375 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CABLE HARNESS-DPU MODEL POSITIONING SET

DATE APR 21,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	2.0	30	4.00	.04000	.32000	217A	
CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	
S3 CONNECTOR, 36 PINS	7.0	30	6.00	1.22500	15.43501	217A	
CONNECTOR, 20 PINS	.5	30	6.00	.48600	1.45800	217A	

TOTAL FAILURE RATE EQUALS 18.24200 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 54818.5352 HOURS

DESIGN FAILURE RATE GOAL 27.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE MEMORY PWR SUP MODEL AIRBORNE PWS SET

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.17000	.10200	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	8.00	.08650	1.38400	217A	
	COIL, AUDIO	1.0	30	10.00	.20000	2.00000	217A	
	DIODE, SILICON, 0-1 WATT	15.0	30	3.50	.25500	13.38750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	10.00	.00400	.07600	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.30	.17000	.00102	217A	
	TRANSFORMER, POWER	1.0	30	10.00	.22000	2.20000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	8.00	.25500	8.16000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	8.00	.51000	4.08000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	8.00	.67000	16.07999	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	3.00	.77000	6.93000	217A	
	CAPACITOR, CER, CK	3.0	30	5.00	.00640	.09600	217A	
	CONNECTOR, 15 PINS	.5	30	6.00	.34300	1.02900	217A	

TOTAL FAILURE RATE EQUALS 55.68042 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 17959.6328 HOURS

DESIGN FAILURE RATE GOAL 60.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE AIRBORNE MEMORY MODEL AIRBORNE POS SET

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	5.0	30	5.00	.00640	.16000	217A	
	CAPACITOR, SLD TANT, CSR	17.0	30	1.00	.17000	.28900	217A	
	CONNECTOR, 10 PINS	9.0	30	6.00	.22200	11.98800	217A	
S3	CONNECTOR, 20 PINS	15.0	30	6.00	.48600	13.12201	217A	
S3	DIODE, SILICON, 0-1 WATT	50.0	30	3.50	.25500	13.38750	217A	
	INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	.40000	16.39999	217A	
	INTEGRATED CIRCUIT, LINEAR	41.0	30	1.00	.40000	16.39999	217A	
	RESISTOR, FIXED METAL FILM	92.0	30	.30	.17000	4.69200	217A	
S4	RESISTOR, FIXED WIRE WOUND	21.0	30	3.00	1.05500	6.64650	217A	
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	14.0	30	8.00	.25500	8.56801	217A	
	ZENER DIODE, 0-1 WATT	2.0	30	3.00	.77000	4.62000	217A	
	CORES, FERRITE	31 201.0	30	1.00	.00002	.49922	217A	
	CORES, FERRITE	99 999.0	30	1.00	.00002	1.59998	217A	

TOTAL FAILURE RATE EQUALS 98.37216 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10165.4766 HOURS

DESIGN FAILURE RATE GOAL 110.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FILTER , AIRBORNE   MODEL POSITION SET,AIR

DATE APR 21,'71   TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	5.0	30	1.00	.03500	.17500	217A	

TOTAL FAILURE RATE EQUALS .17500 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 5714285.0000 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CONTROL & MONITOR MODEL POSITION SET,AIR

DATE APR 21,'71 TEMP 50. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
S3	COIL, RF	11.0	30	8.60	.22000	6.24360	217A	
	CONNECTOR, 8 PINS	1.0	30	6.00	.18200	1.09200	217A	
	CONNECTOR, 36 PINS	1.0	30	6.00	1.22500	7.35000	217A	
S3	SWITCH, TOGGLE OR PUSHBUTTON	7.0	30	18.00	.25000	9.45001	217A	

TOTAL FAILURE RATE EQUALS 24.13559 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 41432.5898 HOURS

DESIGN FAILURE RATE GOAL 25.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RUBIDIUM FREQ STD MODEL AIRBORNE PBS SET

DATE APR 21,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, ALUM ELECT, CE	3.0	30	.60	.23500	.51300	217A	
CAPACITOR, GLASS, CY	4.0	30	18.00	.02300	1.65600	217A	
CAPACITOR, CER, CK	52.0	30	5.00	.00640	1.66400	217A	
CAPACITOR, MICA, CM	74.0	30	15.00	.00071	.79365	217A	
CAPACITOR, FD-THRU	12.0	30	5.00	.02400	1.44000	217A	
CAPACITOR, MYLAR, CTM	13.0	30	10.00	.00125	.16250	217A	
CAPACITOR, SLD TANT, CSR	82.0	30	1.00	.17000	1.39400	217A	
CAPACITOR, VAR CER, CV	3.0	30	1.00	.03500	.10500	217A	
S3 COIL, RF	49.0	30	8.60	.22000	27.81241	217A	
CONNECTOR, RF	36.0	30	4.00	.04000	5.76000	217A	
CONNECTOR, 8 PINS	2.0	30	6.00	.18200	2.18400	217A	
CONNECTOR, 20 PINS	3.0	30	6.00	.48600	8.74800	217A	
CRYSTAL, QUARTZ	3.0	30	1.00	.02000	.06000	217A	
DIODE, GERMANIUM, 0-1 WATT	2.0	30	3.50	2.55000	17.84999	217A	
DIODE, SILICON, 0-1 WATT	34.0	30	3.50	.25500	30.34499	217A	
DIODE, SILICON, 1-50 WATT	8.0	30	12.00	.43000	41.28000	217A	
FILTER, FEED THRU	1.0	30	1.00	.02400	.02400	217A	
FUSE	3.0	30	1.00	.10000	.30000	217A	
INTEGRATED CIRCUIT, DIGITAL	16.0	30	1.00	.40000	6.40000	217A	
INTEGRATED CIRCUIT, LINEAR	10.0	30	1.00	.40000	4.00000	217A	
METER	1.0	30	1.00	.50000	.50000	217A	
RELAY, HALF CRYSTAL CAN	1.0	30	50.00	.00310	.15500	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	295.0	30	10.00	.00400	1.18000	217A	
S4 RESISTOR, FIXED METAL FILM	47.0	30	.30	.17000	.02397	217A	
RESISTOR, FIXED WIRE WOUND	2.0	30	3.00	1.05500	6.33000	217A	
S3 RESISTOR, NON-WW VAR. L. S. ACT.	10.0	30	2.00	39.30000	78.60010	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	5.0	30	18.00	.09600	8.64000	RADC	
S3 SWITCH, TOGGLE OR PUSHBUTTON	16.0	30	18.00	.25000	21.60001	217A	
THERMISTOR	2.0	30	1.00	.30000	.60000	217A	
TRANSFORMER, POWER	1.0	30	10.00	.22000	2.20000	217A	
TRANSFORMER, RF	10.0	30	10.00	.22000	22.00000	217A	

	TRANSISTOR, FIELD EFFECT	3.0	30	8.00	.67000	16.07999	217A
	TRANSISTOR, GERMANIUM PNP, 1-50 WATT	2.0	30	8.00	2.10000	33.60001	217A
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	62.0	30	8.00	.25500	37.94400	217A
	TRANSISTOR, SILICON NPN, 1-50 WATT	10.0	30	8.00	.51000	40.79999	217A
S3	TRANSISTOR, SILICON PNP, 0-1 WATT	11.0	30	8.00	.67000	17.68800	217A
	TRANSISTOR, SILICON PNP, 1-50 WATT	2.0	30	8.00	1.34000	21.44000	217A
	VARICAP	4.0	30	3.50	.25500	3.57000	217A
	ZENER DIODE, 0-1 WATT	8.0	30	3.00	.77000	18.48000	217A
	ZENER DIODE, 1-50 WATT	1.0	30	3.00	.77000	2.31000	217A

TOTAL FAILURE RATE EQUALS 486.23047 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 2056.6377 HOURS

DESIGN FAILURE RATE GOAL 25.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE OUTSIDE CABLES MODEL LRPDS SYSTEM

DATE APR 21,'71 TEMP 50. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	1.0	30	4.00	.04000	.16000	217A	
CONNECTOR, 8 PINS	2.0	30	6.00	.18200	2.18400	217A	

TOTAL FAILURE RATE EQUALS 2.34400 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 426621.3125 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   TOTAL OF ALL MODULES

DATE APR 21,'71   TEMP   50. C

TOTAL FAILURE RATE EQUALS   1258.64673 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   794.5039 HOURS

APPENDIX F-4.6

RELIABILITY TEST CONDITION

RELIABILITY PREDICTION DATA SHEETS

REFERENCE POSITION SET AN/ASQ-148

ENVIRONMENT: GROUND

TEMPERATURE: +25°C

STRESS LEVELS: 30% (ASSUMED) EXCEPT
RUBIDUM STANDARD STRESSES
10% (ASSUMED)

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER CONVERTER   MODEL R/T UNIT

DATE APR 21, '71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	3.0	30	1.00	.00512	.01537	217A	
CAPACITOR, SLD TANT, CSR	9.0	30	1.00	.11000	.09900	217A	
CAPACITOR, FOIL TANT, CL	2.0	30	1.00	.06600	.13200	217A	
COIL, RF	8.0	30	1.00	.22000	1.76000	217A	
DIODE, SILICON, 0-1 WATT	8.0	30	1.50	.25500	3.06000	217A	
DIODE, SILICON, 1-50 WATT	1.0	30	1.00	.43000	.43000	217A	
FILTER, FEED THRU	9.0	30	1.00	.01000	.09000	217A	
RESISTOR, FIXED CARBON COMPOSITION	8.0	30	6.00	.00350	.01680	217A	
RESISTOR, FIXED METAL FILM	4.0	30	.03	.12000	.01440	217A	
TRANSFORMER, RF	1.0	30	1.50	.22000	.33000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	.51000	.51000	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	1.50	.67000	2.01000	217A	
ZENER DIODE, 0-1 WATT	1.0	30	1.00	.77000	.77000	217A	
CONNECTOR, 8 PINS	1.0	30	1.10	.18200	.20020	217A	

TOTAL FAILURE RATE EQUALS   9.82027 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   101830.1875 HOURS

DESIGN FAILURE RATE GOAL   44.00000 FAILURES PER MILLION HOURS

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S4

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RF/IF MODEL R/T UNIT

DATE APR 21, '71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	15.0	30	1.00	.00512	.07687	217A	
CAPACITOR, MICA, CM	2.0	30	1.40	.00052	.00145	217A	
COIL, RF	1.0	30	1.00	.22000	.22000	217A	
CONNECTOR, RF	3.5	30	1.10	.04000	.15400	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
INTEGRATED CIRCUIT, LINEAR	5.0	30	1.00	.40000	2.00000	217A	
RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	19.0	30	6.00	.00350	.03990	217A	
S3 RESISTOR, NON-WW VAR. _. S. ACT.	1.0	30	.10	33.42499	.33425	217A	1
DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
TRANSFORMER, RF	2.0	30	1.50	.22000	.66000	217A	
CAPACITOR, VAR AIR, CT	2.0	30	1.00	.02250	.04500	217A	

TOTAL FAILURE RATE EQUALS 7.62787 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 131098.1875 HOURS

DESIGN FAILURE RATE GOAL 19.00000 FAILURES PER MILLION HOURS

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE
DUE TO NO FIELD ADJUSTMENTS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE POWER AMPLIFIER   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	61.0	30	1.00	.00512	.31262	217A	
COIL, RF	24.0	30	1.00	.22000	5.28000	217A	
CONNECTOR, RF	1.5	30	1.10	.04000	.06600	217A	
DIODE, HOT CARRIER	3.0	30	1.50	.65000	2.92500	217A	
DIODE, SILICON, 0-1 WATT	8.0	30	1.50	.25500	3.06000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	33.0	30	6.00	.00350	.06930	217A	
TRANSFORMER, RF	10.0	30	1.50	.22000	3.30000	217A	
TRANSISTOR, FIELD EFFECT	9.0	30	1.50	.67000	9.04500	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	9.0	30	1.00	.51000	4.59000	217A	
CONNECTOR, 36 PINS	.5	30	1.10	1.22500	.67375	217A	

TOTAL FAILURE RATE EQUALS 29.70415 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 33665.3320 HOURS

DESIGN FAILURE RATE GOAL 95.00000 FAILURES PER MILLION HOURS

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MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE XMTR MODULATOR   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	6.0	30	1.00	.00512	.03075	217A	
CAPACITOR, SLD TANT, CSR	2.0	30	1.00	.11000	.02200	217A	
COIL, RF	2.0	30	1.00	.22000	.44000	217A	
DIODE, HOT CARRIER	8.0	30	1.50	.65000	7.80000	217A	
DIODE, SILICON, 0-1 WATT	10.0	30	1.50	.25500	3.82500	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
RELAY, HALF CRYSTAL CAN	3.0	30	2.50	.00310	.02325	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	30.0	30	6.00	.00350	.06300	217A	
TRANSFORMER, RF	4.0	30	1.50	.22000	1.32000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	10.0	30	1.50	.25500	3.82500	217A	
ZENER DIODE, 0-1 WATT	1.0	30	1.00	.77000	.77000	217A	

TOTAL FAILURE RATE EQUALS   18.91898 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   52856.9805 HOURS

DESIGN FAILURE RATE GOAL   52.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREQ SYN 1 (XMTR)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	22.0	30	1.00	.00512	.11275	217A	
	CAPACITOR, MICA, CM	16.0	30	1.40	.00052	.01159	217A	
	COIL, RF	8.0	30	1.00	.22000	1.76000	217A	
	DIODE, HOT CARRIER	12.0	30	1.50	.65000	11.70000	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
	INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	57.0	30	6.00	.00350	.11970	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	1.50	.25500	2.29500	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	1.50	.67000	2.01000	217A	
	TRANSFORMER, RF	4.0	30	1.50	.22000	1.32000	217A	
	RESISTOR, VARIABLE, 10-TURN	1.0	30	1.00	1.01500	1.01500	SM-188	

TOTAL FAILURE RATE EQUALS   23.05650 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   43371.7109 HOURS

DESIGN FAILURE RATE GOAL   66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FREQ SYN 2 (REC)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	22.0	30	1.00	.00512	.11275	217A	
CAPACITOR, MICA, CM	16.0	30	1.40	.00052	.01159	217A	
COIL, RF	8.0	30	1.00	.22000	1.76000	217A	
DIODE, HOT CARRIER	12.0	30	1.50	.65000	11.70000	217A	
DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
INTEGRATED CIRCUIT, LINEAR	2.0	30	1.00	.40000	.80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	57.0	30	6.00	.00350	.11970	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	6.0	30	1.50	.25500	2.29500	217A	
TRANSISTOR, SILICON PNP, 0-1 WATT	2.0	30	1.50	.67000	2.01000	217A	
TRANSFORMER, RF	4.0	30	1.50	.22000	1.32000	217A	
RESISTOR, VARIABLE, 10-TURN	1.0	30	1.00	1.01500	1.01500	SM-188	
CONNECTOR, RF	3.0	30	1.10	.04000	.13200	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	

TOTAL FAILURE RATE EQUALS   23.37714 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   42776.8359 HOURS

DESIGN FAILURE RATE GOAL   66.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CARRIER IG/VCO   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	2.0	30	1.00	.02250	.04500	217A	
	CAPACITOR, CER, CK	72.0	30	1.00	.00512	.36900	217A	
	CAPACITOR, MICA, CM	14.0	30	1.40	.00052	.01014	217A	
	COIL, RF	6.0	30	1.00	.22000	1.32000	217A	
	CONNECTOR, RF	3.0	30	1.10	.04000	.13200	217A	
	CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
	DIODE, SILICON, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
	INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
	INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	7.60000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	80.0	30	6.00	.00350	.16800	217A	
	RESISTOR, FIXED METAL FILM	27.0	30	.03	.12000	.09720	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	3.0	30	18.00	.07100	3.83400	RADC	
	TRANSISTOR, SILICON NPN, 0-1 WATT	5.0	30	1.50	.25500	1.91250	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	1.00	.77000	2.31000	217A	
	DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
	TRANSFORMER, RF	2.0	30	1.50	.22000	.66000	217A	
	CRYSTAL, QUARTZ	3.0	30	1.00	.02000	.06000	217A	
	CAPACITOR, T C CER, CC	4.0	30	1.00	.00275	.01100	217A	
	CAPACITOR, VAR GLASS, PC	1.0	30	1.00	.02475	.02475	217A	
	CAPACITOR, VAR CER, CV	1.0	30	1.00	.02250	.02250	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.03	.12000	.00007	217A	

TOTAL FAILURE RATE EQUALS   25.77724 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   38793.9141 HOURS

DESIGN FAILURE RATE GOAL   54.00000 FAILURES PER MILLION HOURS

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MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CODE DETECTOR   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	46.0	30	1.00	.00512	.23575	217A	
CAPACITOR, MICA, CM	4.0	30	1.40	.00052	.00290	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
DIODE, SILICON, 0-1 WATT	7.0	30	1.50	.25500	2.67750	217A	
INTEGRATED CIRCUIT, DIGITAL	3.0	30	1.00	.40000	1.20000	217A	
INTEGRATED CIRCUIT, LINEAR	19.0	30	1.00	.40000	7.60000	217A	
RESISTOR, FIXED METAL FILM	28.0	30	.03	.12000	.10080	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	

TOTAL FAILURE RATE EQUALS   13.66609 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   73173.7500 HOURS

DESIGN FAILURE RATE GOAL   16.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CACU (DIGITAL)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	30.0	30	1.00	.00512	.15375	217A	
INTEGRATED CIRCUIT, DIGITAL	71.0	30	1.00	.40000	28.39999	217A	
RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	54.0	30	6.00	.00350	.11340	217A	
CAPACITOR, MICA, CM	6.0	30	1.40	.00052	.00435	217A	
COIL, RF	3.0	30	1.00	.22000	.66000	217A	
CONNECTOR, RF	6.0	30	1.10	.04000	.26400	217A	
CONNECTOR, 36 PINS	.5	30	1.10	1.22500	.67375	217A	

TOTAL FAILURE RATE EQUALS 30.27692 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 33028.4609 HOURS

DESIGN FAILURE RATE GOAL 20.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CACU (DIGITAL)   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	30.0	30	1.00	.00512	.15375	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	71.0	30	1.00	.40000	8.52000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	6.00	.00350	.11340	217A	
	CAPACITOR, MICA, CM	6.0	30	1.40	.00052	.00435	217A	
	COIL, RF	3.0	30	1.00	.22000	.66000	217A	
	CONNECTOR, RF	6.0	30	1.10	.04000	.26400	217A	
	CONNECTOR, 36 PINS	.5	30	1.10	1.22500	.67375	217A	

TOTAL FAILURE RATE EQUALS 10.39693 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 96182.2500 HOURS

DESIGN FAILURE RATE GOAL 20.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CLOCK IG DETECTOR MODEL R/T UNIT

DATE APR 21,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	30	1.00	.02250	.02250	217A	
CAPACITOR, CER, CK	36.0	30	1.00	.00512	.18450	217A	
CAPACITOR, MICA, CM	10.0	30	1.40	.00052	.00724	217A	
COIL, RF	6.0	30	1.00	.22000	1.32000	217A	
CONNECTOR, RF	3.0	30	1.10	.04000	.13200	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
DIODE, SILICON, 0-1 WATT	2.0	30	1.50	.25500	.76500	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	48.0	30	6.00	.00350	.10080	217A	
RESISTOR, FIXED METAL FILM	13.0	30	.03	.12000	.04680	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSFORMER, RF	6.0	30	1.50	.22000	1.98000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	2.0	30	1.50	.25500	.76500	217A	
ZENER DIODE, 0-1 WATT	1.0	30	1.00	.77000	.77000	217A	
DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
CAPACITOR, T C CER, CC	4.0	30	1.00	.00275	.01100	217A	
CRYSTAL, QUARTZ	2.0	30	1.00	.02000	.04000	217A	

TOTAL FAILURE RATE EQUALS 16.31146 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 61306.5781 HOURS

DESIGN FAILURE RATE GOAL 36.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CLOCK PHASE CONTROL   MODEL R/T UNIT

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	38.0	30	1.00	.00512	.19475	217A	
CAPACITOR, MICA, CM	4.0	30	1.40	.00052	.00290	217A	
COIL, RF	5.0	30	1.00	.22000	1.10000	217A	
DIODE, SILICON, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
INTEGRATED CIRCUIT, DIGITAL	4.0	30	1.00	.40000	1.60000	217A	
INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	28.0	30	6.00	.00350	.05880	217A	
RESISTOR, FIXED METAL FILM	10.0	30	.03	.12000	.03600	217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSFORMER, RF	5.0	30	1.50	.22000	1.65000	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	
DIODE, HOT CARRIER	4.0	30	1.50	.65000	3.90000	217A	
CAPACITOR, T C CER, CC	8.0	30	1.00	.00275	.02200	217A	
CRYSTAL, QUARTZ	4.0	30	1.00	.02000	.08000	217A	

TOTAL FAILURE RATE EQUALS 15.48744 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 64568.4453 HOURS

DESIGN FAILURE RATE GOAL 30.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RTJ CABLE HARNESS MODEL POSITIONING SET

DATE APR 21,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	18.0	30	1.10	.04000	.79200	217A	
CONNECTOR, 8 PINS	2.0	30	1.10	.18200	.40040	217A	
CONNECTOR, 15 PINS	3.0	30	1.10	.34300	1.13190	217A	
CONNECTOR, 36 PINS	1.5	30	1.10	1.22500	2.02125	217A	

TOTAL FAILURE RATE EQUALS 4.34555 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 230120.4375 HOURS

DESIGN FAILURE RATE GOAL 12.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE RCDU-DPU MODEL POSITIONING SET

DATE APR 21,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	65.0	30	1.00	.00512	.34850	217A	
	CAPACITOR, T C CER, CC	2.0	30	1.00	.00275	.00550	217A	
	CAPACITOR, MICA, CM	20.0	30	1.40	.00052	.01449	217A	
	CAPACITOR, SLD TANT, CSR	5.0	30	1.00	.11000	.05500	217A	
	COIL, AUDIO	1.0	30	1.50	.20000	.30000	217A	
	COIL, RF	3.0	30	1.00	.22000	.66000	217A	
S_3	INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	.40000	4.92000	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	30	1.00	.40000	4.80000	217A	
S_4	RESISTOR, FIXED CARBON COMPOSITION	54.0	30	6.00	.00350	.11340	217A	
	RESISTOR, FIXED METAL FILM	8.0	30	.03	.12000	.02880	217A	
	TRANSFORMER, RF	2.0	30	1.50	.22000	.66000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	1.0	30	1.50	.25500	.38250	217A	

TOTAL FAILURE RATE EQUALS 12.28813 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 81379.3125 HOURS

DESIGN FAILURE RATE GOAL 21.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU PWR SUP MODEL POSITIONING SET

DATE APR 21,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.11000	.06600	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	1.00	.06600	.13200	217A	
	COIL, AUDIO	1.0	30	1.50	.20000	.30000	217A	
	DIODE, SILICON, 0-1 WATT	15.0	30	1.50	.25500	5.73750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	6.00	.00350	.03990	217A	
S4	RESISTOR, FIXED METAL FILM	2.0	30	.03	.12000	.00007	217A	
	TRANSFORMER, POWER	1.0	30	1.50	.22000	.33000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	1.50	.25500	1.53000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	.51000	.51000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	1.50	.67000	3.01500	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	1.00	.77000	2.31000	217A	
	CAPACITOR, CER, CK	3.0	30	1.00	.00512	.01537	217A	
	CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	

TOTAL FAILURE RATE EQUALS 14.18224 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 70510.6875 HOURS

DESIGN FAILURE RATE GOAL 46.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU WORD CONTROL MODEL POSITIONING SET

DATE APR 21,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	1.00	.00512	.07687	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	5.0	30	6.00	.00350	.01050	217A	

TOTAL FAILURE RATE EQUALS 6.71486 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 148923.4375 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU MSG OUTPUT CTRL MODEL POSITIONING SET

DATE APR 21,'71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	16.0	30	1.00	.00512	.08200	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	47.0	30	1.00	.40000	5.64000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	18.0	30	6.00	.00350	.03780	217A	

TOTAL FAILURE RATE EQUALS 7.10728 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 140700.7500 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE DPJ DATA ASMBLR & ST   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	15.0	30	1.00	.00512	.07687	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	46.0	30	1.00	.40000	5.52000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	6.0	30	6.00	.00350	.01260	217A	

TOTAL FAILURE RATE EQUALS   6.95695 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   143741.1250 HOURS

DESIGN FAILURE RATE GOAL   13.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DPU COMMAND DECODER MODEL POSITIONING SET

DATE APR 21, '71 TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, CER, CK	14.0	30	1.00	.00512	.07175	217A	
	CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
S3	INTEGRATED CIRCUIT, DIGITAL	44.0	30	1.00	.40000	5.28000	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	20.0	30	6.00	.00350	.04200	217A	
	CAPACITOR, SLD TANT, CSR	1.0	30	1.00	.11000	.01100	217A	

TOTAL FAILURE RATE EQUALS 6.75223 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 148099.2500 HOURS

DESIGN FAILURE RATE GOAL 13.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE CABLE HARNESS-DPJ   MODEL POSITIONING SET

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	2.0	30	1.10	.04000	.08800	217A	
CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	
CONNECTOR, 36 PINS	7.0	30	1.10	1.22500	9.43251	217A	
CONNECTOR, 20 PINS	.5	30	1.10	.48600	.26730	217A	

TOTAL FAILURE RATE EQUALS   9.97645 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   100236.0000 HOURS

DESIGN FAILURE RATE GOAL   27.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE MEMORY PWR SUP   MODEL AIRBORNE POS SET

DATE APR 21,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, SLD TANT, CSR	6.0	30	1.00	.11000	.06600	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	1.00	.06600	.13200	217A	
	COIL, AUDIO	1.0	30	1.50	.20000	.30000	217A	
	DIODE, SILICON, 0-1 WATT	15.0	30	1.50	.25500	5.73750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S*	RESISTOR, FIXED CARBON COMPOSITION	19.0	30	6.00	.00350	.03990	217A	
S*	RESISTOR, FIXED METAL FILM	2.0	30	.03	.12000	.00007	217A	
	TRANSFORMER, POWER	1.0	30	1.50	.22000	.33000	217A	
	TRANSISTOR, SILICON NPN, 0-1 WATT	4.0	30	1.50	.25500	1.53000	217A	
	TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	.51000	.51000	217A	
	TRANSISTOR, SILICON PNP, 0-1 WATT	3.0	30	1.50	.67000	3.01500	217A	
	ZENER DIODE, 0-1 WATT	3.0	30	1.00	.77000	2.31000	217A	
	CAPACITOR, CER, CK	3.0	30	1.00	.00512	.01537	217A	
	CONNECTOR, 15 PINS	.5	30	1.10	.34300	.18865	217A	

TOTAL FAILURE RATE EQUALS   14.18224 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   70510.6875 HOURS

DESIGN FAILURE RATE GOAL   60.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE AIRBORNE MEMORY MODEL AIRBORNE POS SET

DATE APR 21,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	5.0	30	1.00	.00512	.02562	217A	
CAPACITOR, SLD TANT, CSR	17.0	30	1.00	.11000	.18700	217A	
CONNECTOR, 10 PINS	9.0	30	1.10	.22200	2.19780	217A	
CONNECTOR, 20 PINS	15.0	30	1.10	.48600	8.01900	217A	
DIODE, SILICON, 0-1 WATT	50.0	30	1.50	.25500	19.12498	217A	
INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	.40000	16.39999	217A	
INTEGRATED CIRCUIT, LINEAR	41.0	30	1.00	.40000	16.39999	217A	
RESISTOR, FIXED METAL FILM	92.0	30	.03	.12000	.33120	217A	
RESISTOR, FIXED WIRE WOUND	21.0	30	1.00	.94750	19.89749	217A	
TRANSISTOR, SILICON NPN, 0-1 WATT	14.0	30	1.50	.25500	5.35500	217A	
ZENER DIODE, 0-1 WATT	2.0	30	1.00	.77000	1.54000	217A	
CORES, FERRITE	201.0	30	1.00	.00002	.49922	217A	
CORES, FERRITE	999.0	30	1.00	.00002	1.59998	217A	

TOTAL FAILURE RATE EQUALS 91.57724 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 10919.7422 HOURS

DESIGN FAILURE RATE GOAL 110.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE FILTER , AIRBORNE   MODEL POSITION SET,AIR

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, VAR AIR, CT	5.0	30	1.00	.02250	.11250	217A	

TOTAL FAILURE RATE EQUALS   .11250 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 8888892.0000 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE CONTROL & MONITOR MODEL POSITION SET,AIR

DATE APR 21,'71 TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
COIL, RF	11.0	30	1.00	.22000	2.42000	217A	
CONNECTOR, 8 PINS	1.0	30	1.10	.18200	.20020	217A	
CONNECTOR, 36 PINS	1.0	30	1.10	1.22500	1.34750	217A	
SWITCH, TOGGLE OR PUSHBUTTON	7.0	30	1.00	.25000	1.75000	217A	

TOTAL FAILURE RATE EQUALS 5.71770 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 174895.4375 HOURS

DESIGN FAILURE RATE GOAL 25.00000 FAILURES PER MILLION HOURS

X

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE RUBIDIUM FREQ STD   MODEL AIRBORNE POS SET

DATE APR 21,'71   TEMP 25. C

	COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
	CAPACITOR, ALUM ELECT, CE	3.0	30	.10	.16750	.05025	217A	
	CAPACITOR, GLASS, CY	4.0	30	1.00	.00773	.03090	217A	
	CAPACITOR, CER, CK	52.0	30	1.00	.00512	.26650	217A	
	CAPACITOR, MICA, CM	74.0	30	1.40	.00052	.05361	217A	
	CAPACITOR, FD-THRU	12.0	30	1.00	.01000	.12000	217A	
	CAPACITOR, MYLAR, CTM	13.0	30	2.00	.00102	.02665	217A	
	CAPACITOR, SLD TANT, CSR	82.0	30	1.00	.11000	.90200	217A	
	CAPACITOR, VAR CER, CV	3.0	30	1.00	.02250	.06750	217A	
	COIL, RF	49.0	30	1.00	.22000	3.23400	217A	
	CONNECTOR, RF	36.0	30	1.10	.04000	1.58400	217A	
	CONNECTOR, 8 PINS	2.0	30	1.10	.18200	.40040	217A	
	CONNECTOR, 20 PINS	3.0	30	1.10	.48600	1.60380	217A	
	CRYSTAL, QUARTZ	3.0	30	1.00	.02000	.06000	217A	
	DIODE, GERMANIUM, 0-1 WATT	2.0	30	.75	2.55000	3.82500	217A	
S3	DIODE, SILICON, 0-1 WATT	34.0	30	1.50	.25500	3.90150	217A	
	DIODE, SILICON, 1-50 WATT	8.0	30	1.00	.43000	3.44000	217A	
	FILTER, FEED THRU	1.0	30	1.00	.01000	.01000	217A	
	FUSE	3.0	30	1.00	.10000	.30000	217A	
	INTEGRATED CIRCUIT, DIGITAL	16.0	30	1.00	.40000	6.40000	217A	
	INTEGRATED CIRCUIT, LINEAR	10.0	30	1.00	.40000	4.00000	217A	
	METER	1.0	30	1.00	.50000	.50000	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	.00310	.00775	217A	
S4	RESISTOR, FIXED CARBON COMPOSITION	295.0	30	6.00	.00350	.61950	217A	
S4	RESISTOR, FIXED METAL FILM	47.0	30	.03	.12000	.00169	217A	
	RESISTOR, FIXED WIRE WOUND	2.0	30	1.00	.94750	1.89500	217A	
S3	RESISTOR, NON-WW VAR. L. S. ACT.	10.0	30	.10	33.42499	3.34251	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	5.0	30	18.00	.07100	6.39000	RADC	
	SWITCH, TOGGLE OR PUSHBUTTON	16.0	30	1.00	.25000	4.00000	217A	
	THERMISTOR	2.0	30	1.00	.30000	.60000	217A	
	TRANSFORMER, POWER	1.0	30	1.50	.22000	.33000	217A	
	TRANSFORMER, RF	10.0	30	1.50	.22000	3.30000	217A	

S3	TRANSISTOR, FIELD EFFECT	3.0	30	1.50	.67000	3.01500	217A
	TRANSISTOR, GERMANIUM PNP, 1-50 WATT	2.0	30	1.00	2.10000	4.20000	217A
S3	TRANSISTOR, SILICON NPN, 0-1 WATT	62.0	30	1.50	.25500	7.11450	217A
	TRANSISTOR, SILICON NPN, 1-50 WATT	10.0	30	1.00	.51000	5.10000	217A
S3	TRANSISTOR, SILICON PNP, 0-1 WATT	11.0	30	1.50	.67000	3.31650	217A
	TRANSISTOR, SILICON PNP, 1-50 WATT	2.0	30	1.00	1.34000	2.68000	217A
	VARICAP	4.0	30	1.50	.25500	1.53000	217A
	ZENER DIODE, 0-1 WATT	8.0	30	1.00	.77000	6.16000	217A
	ZENER DIODE, 1-50 WATT	1.0	30	1.00	.77000	.77000	217A

TOTAL FAILURE RATE EQUALS 85.14833 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 11744.2109 HOURS

DESIGN FAILURE RATE GOAL 25.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   MODULE OUTSIDE CABLES   MODEL LRPDS SYSTEM

DATE APR 21,'71   TEMP 25. C

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CONNECTOR, RF	1.0	30	1.10	.04000	.04400	217A	
CONNECTOR, 8 PINS	2.0	30	1.10	.18200	.40040	217A	

TOTAL FAILURE RATE EQUALS .44440 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 2250224.0000 HOURS

MOTOROLA, INC.
FAILURE RATE DETERMINATION

PROJECT 3995-113   TOTAL OF ALL MODULES

DATE APR 21,'71   TEMP   25. C

TOTAL FAILURE RATE EQUALS   459.64917 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS   2175.5723 HOURS

APPENDIX G

MAINTAINABILITY PREDICTION DATA

1.

Data developed in performing the maintainability predictions are included in this appendix. This includes a complete set of maintenance task flow diagrams, task time summaries, and supporting data.

2. PREDICTION PROCEDURE

The maintainability prediction was performed using a task flow analysis and time estimation technique involving the following steps:

a. A maintenance task flow diagram is proposed using the symbology illustrated in Figure G-1. The chart identifies each action performed and logical decision that must be made during each different maintenance action sequence. This diagram contains the following.

(1) Identification of each action that consumes maintenance time.

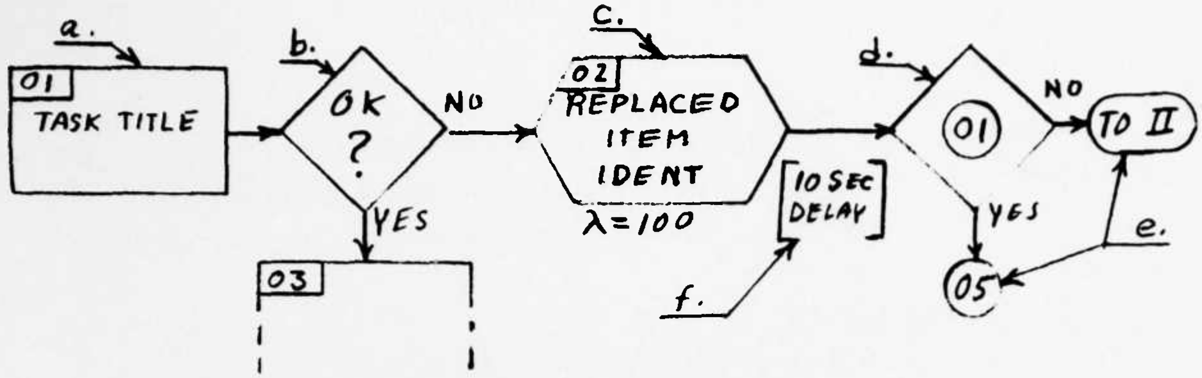
(2) Identification of each logical decision and action taken following the decision.

(3) Failure rates of each module with respect to given failure symptoms and maintenance task sequences.

b. Maintenance tasks are summarized on a worksheet and task time are summed to determine M_{CT} values for each module and failure mode. These values are then weighted by the relative failure rate of the module for the respective failure mode, the weighted values summed, and the results divided by the total failure rate to obtain an $\overline{M}_{CT}$ estimate.

3. ASSUMPTIONS

The maintainability prediction is based on the following assumptions:



LEGEND:

a. PREPARATION OR TEST TASK. BOX CONTAINS:
TASK IDENTIFICATION NUMBER
DESCRIPTIVE TASK TITLE

b. DECISION. BOX INDICATES TYPE OF DECISION MADE AND NEXT ACTION TAKEN FOLLOWING THE DECISION

c. REPLACEMENT TASK. BOX CONTAINS:
TASK IDENTIFICATION NUMBER
IDENTIFICATION OF REPLACED ITEM
REPLACED ITEM FAILURE RATE (λ)

d. RE-TEST ROUTINE. BOX INDICATES ACTION TAKEN FOLLOWING A REPLACEMENT. THE ABOVE EXAMPLE SAYS:

RE-PERFORM TASK 01
MAKE "OK" DECISION INDICATED BY BLOCK b.
GO TO TASK 05 IF "OK" DECISION IS REACHED
GO TO SUBROUTINE II IF "NOT OK" DECISION IS REACHED

e. FLOW CHART ENTRY POINTS: ARABIC NUMERALS INDICATE A TASK IDENTIFICATION NUMBER; ROMAN NUMERALS INDICATE AN ENTRY POINT IN ANOTHER SUBROUTINE

f. TIME DELAYS NOT ASSOCIATED WITH NUMBERED TASKS. E.G., TIME REQUIRED FOR TEST SET TO INDICATE AN ERROR AFTER ONE HAD BEN ENCOUNTERED

Figure G-1. Maintenance Task Flow Diagram Symbology

a. Maintenance time starts after units are placed on the maintenance bench and all necessary equipment and spares are immediately available.

b. All test equipment, including the TCS and auxiliary test equipment are turned on and ready for tests to begin. The time required to connect the unit to the test set is considered as part of the maintenance time. However, warm-up time, such as the time required for oscillator or frequency standard stabilization, is not considered.

c. A maintenance action is completed when correction of the specific failure under consideration has been verified and the equipment returned to serviceable condition. Additional time that may be required to completely check out the remaining functions of the unit are not considered as part of a given corrective maintenance action.

d. The following test equipment is assumed to be available:

Test and Calibration Set. This provides facilities to test all digital circuitry of the DPU and the overall operation of the RTU.

RTU Test Box. This provides test point "break-out" capability for using auxiliary test equipment.

Oscilloscope. This is used for observing certain RTU signal status indications.

Multimeter. This is used for measuring power supply and signal voltage levels.

4. MAINTAINABILITY PREDICTION DATA

Data prepared in performing the maintainability prediction are presented in the following sections of this appendix:

Figure G-2.	Positioning Unit Maintenance Flow Diagram
Figure G-3.	RTU Maintenance Flow Diagram (Receive Functions)
Figure G-4.	RTU Maintenance Flow Diagram (Transmit Functions)
Figure G-5.	Reference Position Unit Maintenance Flow Diagram

Figure G-6.	Positioning Unit Supplementary Maintenance Flow Diagram (P7 Message Sequence)
Table G-1.	Corrective Maintenance Task Time Estimates
Table G-2.	Positioning Set Task Time Summary
Table G-3.	Reference Position Set Task Time Summary (Defined Portions Only)
Table G-4.	RPS Fault Detection Time
Table G-5.	Elemental Task Times

5. REFERENCE POSITION SET MAINTAINABILITY ESTIMATE

Table G-3 summarizes the maintainability prediction data for those portions of the RPS that have been sufficiently defined to date. However, the DPU has not been defined sufficiently to associate functions and failure modes with physical modularization. Therefore, the predictions cannot be completed for these portions.

An estimate of the maintenance time for the DPU is made by determining the approximate times expended before different categories of failures are detected by the TCS. In general, any DPU failure involves one of the following types of operation:

a. Decoding and responding to commands.

b. Generating and transmitting commands.

c. Storing data in memory and reading data out of memory.

Table G-4 indicates the approximate minimum, maximum and average times that are required to detect failures in each of these categories. This includes the time required for the TCS to lock up on an error that would be detected at the earliest possible and latest possible events of the test cycle. Assuming two modules would be replaced before the failure was corrected, the test would be performed three times for an "average" DPU failure; twice for fault isolation and once for final check. Thus, the total troubleshooting time for a given categroy of failure is estimated to be the three times the average time indicated in Table G-4.

It is assumed that there are 9 logic modules, each having a failure rate similar to those of the PS, or approximately 8 f/10^6.

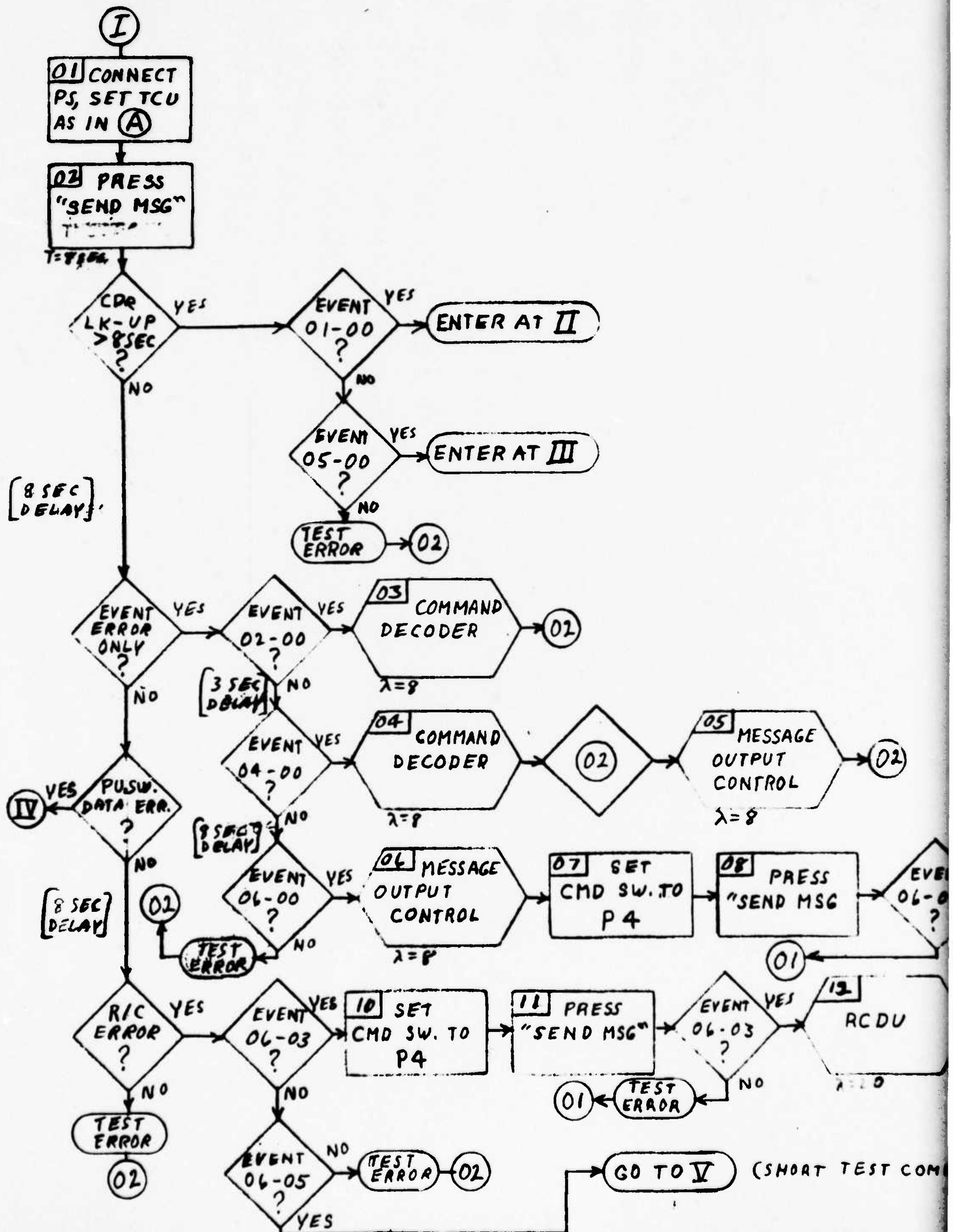
The memory failure rate has been predicted to be 98 $f/10^6$. Assuming two modules are replaced on the average in locating a failure, and set-up time is 15.7 minutes (tasks 60, 61, and 64) the DPU maintenance time is calculated as:

$$\overline{M}_{CT} = \frac{9[15.7 + 3(1.95)](8) + [15.7 + 3(3.9)]98}{72 + 98}$$

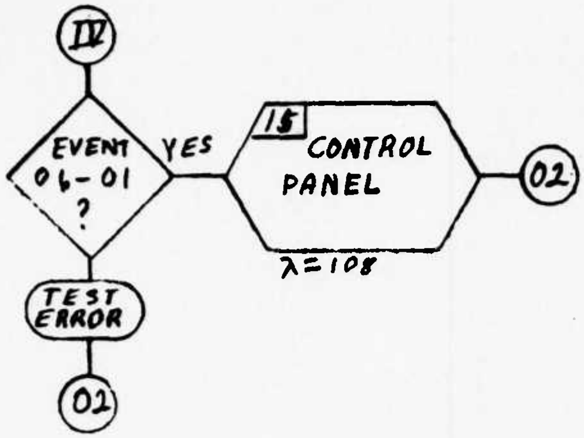
$$= 24.8 \text{ minutes}$$

Combining this with the predicted values for the defined portions of the RPS (Table G-3) gives an estimate of $\overline{M}_{CT}$ for the RPS as:

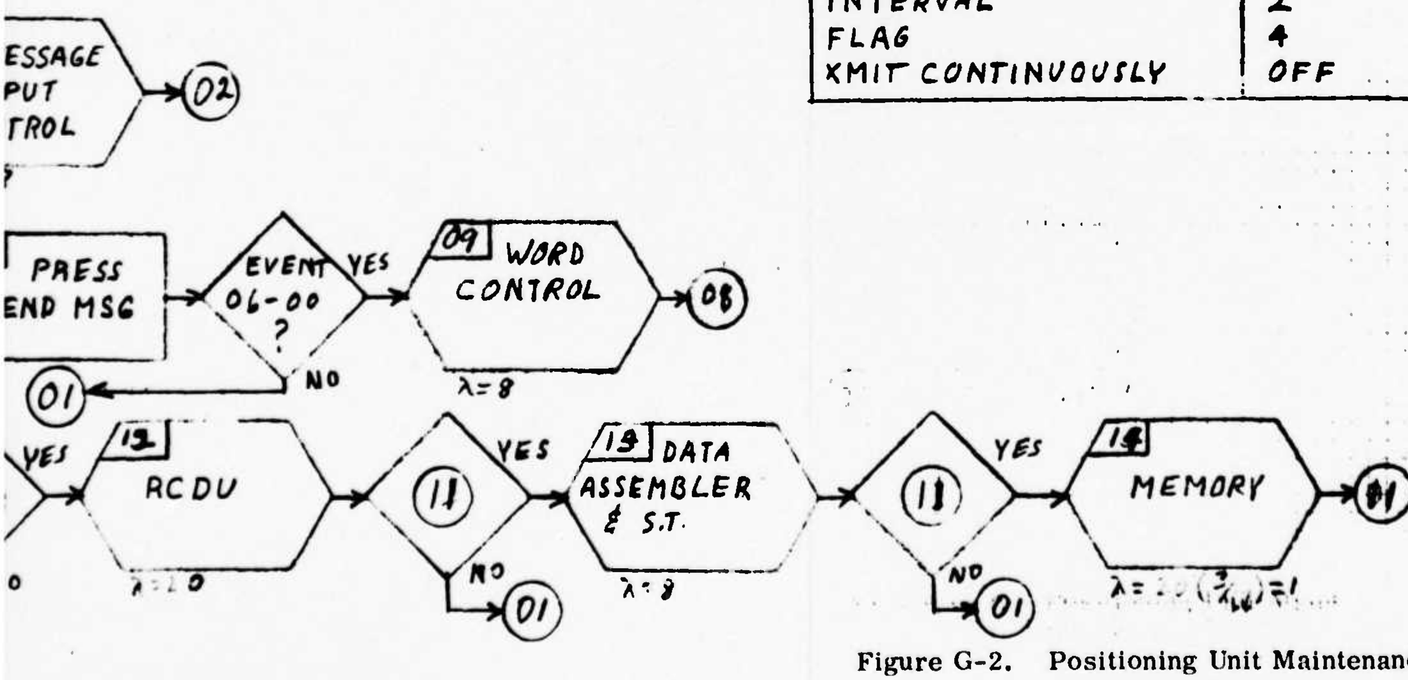
$$\frac{31.2 \times 639 + 24.8 \times 170}{809} = 29.8 \text{ minutes}$$



I
01 CONNECT PS, SET TCU AS IN A
02 PRESS "SEND MSG"
CDR LK-UP >8SEC ?
YES
NO
EVENT 01-00 ?
ENTER AT II
EVENT 05-00 ?
ENTER AT III
TEST ERROR
02
8 SEC DELAY
EVENT ERROR ONLY ?
EVENT 02-00 ?
03 COMMAND DECODER
λ=8
3 SEC DELAY
EVENT 04-00 ?
04 COMMAND DECODER
05 MESSAGE OUTPUT CONTROL
λ=8
PU SW. DATA ERR. ?
IV
8 SEC DELAY
EVENT 06-00 ?
06 MESSAGE OUTPUT CONTROL
07 SET CMD SW. TO P4
08 PRESS "SEND MSG
01
R/C ERROR ?
EVENT 06-03 ?
10 SET CMD SW. TO P4
11 PRESS "SEND MSG"
EVENT 06-03 ?
12 RCDU
EVENT 06-05 ?
GO TO V
(SHORT TEST COM



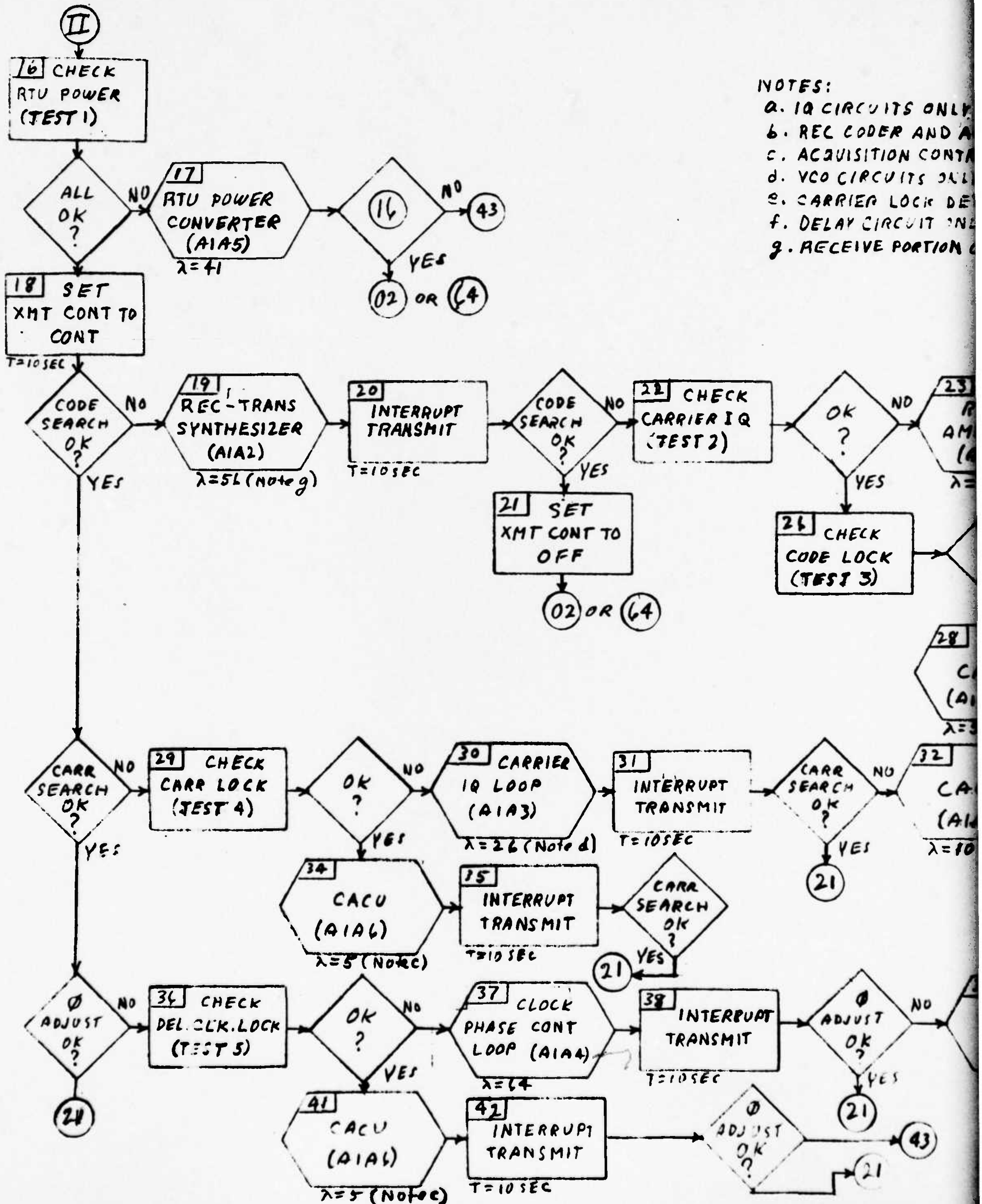
Ⓐ TCU SWITCH SETTINGS	
SWITCH	SETTING
NO OF MEASUREMENTS	03
SLOT	C :
PU IDENT	AS ON [illegible]
CODE SELECT	AS ON PU
PU SW. DATA	AS DESIRE
DIGITAL MSG	AS DESIRED
UUT	PU/DDU
ALTIMETER DATA	NOT USED
COMMAND	P1
INTERVAL	2
FLAG	4
XMIT CONTINUOUSLY	OFF



(SHORT TEST COMPLETED)

Figure G-2. Positioning Unit Maintenance Flow Diagram

NOTES:
a. IQ CIRCUITS ONLY
b. REC CODER AND A
c. ACQUISITION CONTR
d. VCO CIRCUITS ONLY
e. CARRIER LOCK DE
f. DELAY CIRCUIT ONL
g. RECEIVE PORTION



CUITS ONLY
ODER AND ACQ. CONT. ONLY
SITION CONTROL ONLY
IRCUITS ONLY
ER LOCK DETECTOR ONLY
CIRCUIT ONLY
IVE PORTION ONLY

TESTS: (RTU TEST BOX SW. POSITIONS)

1. A-1, A-2, A-3, A-4, A-5, A-6
2. A-7, A-8, A-9
3. A-10
4. A-11
5. A-12

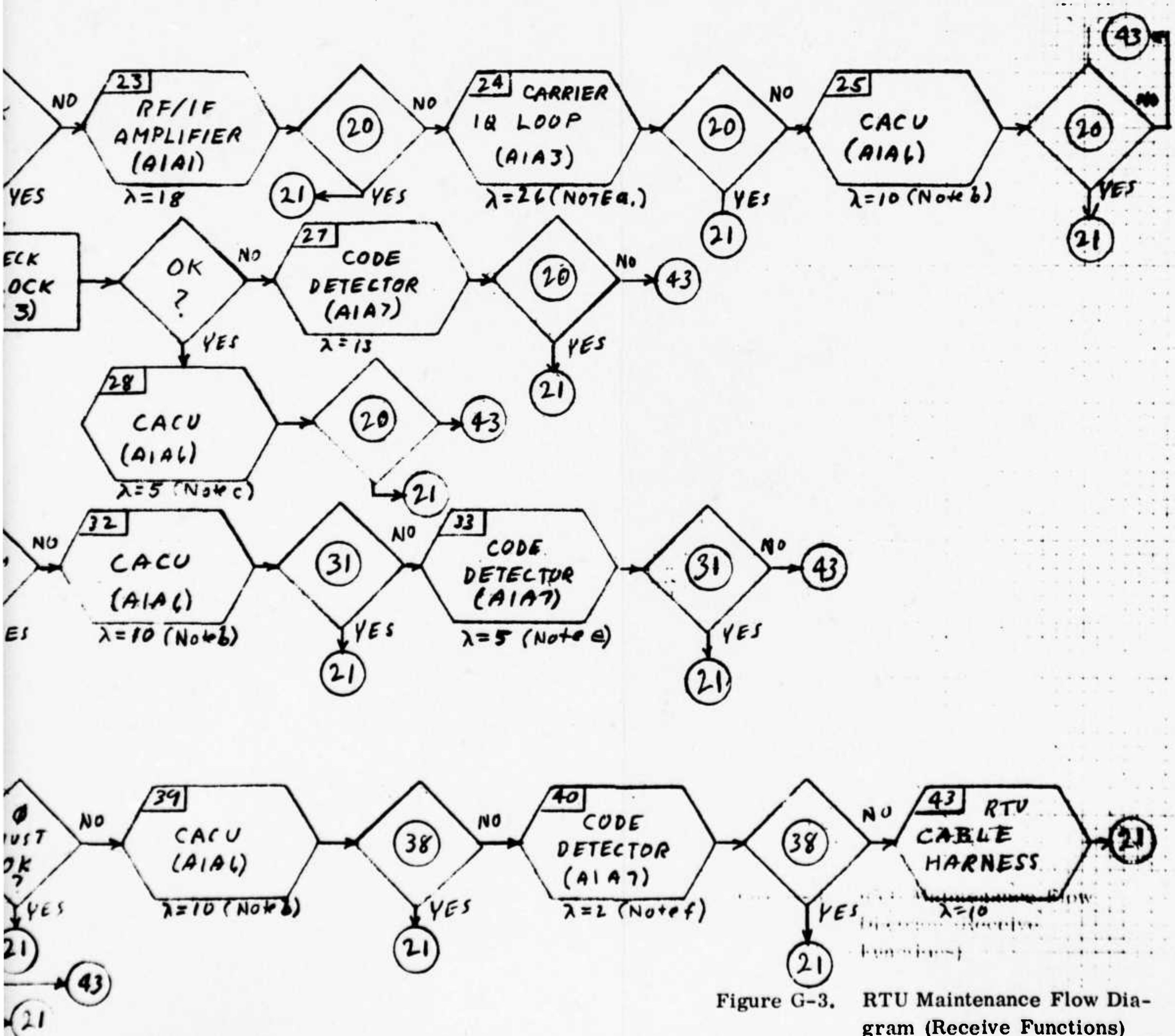


Figure G-3. RTU Maintenance Flow Diagram (Receive Functions)

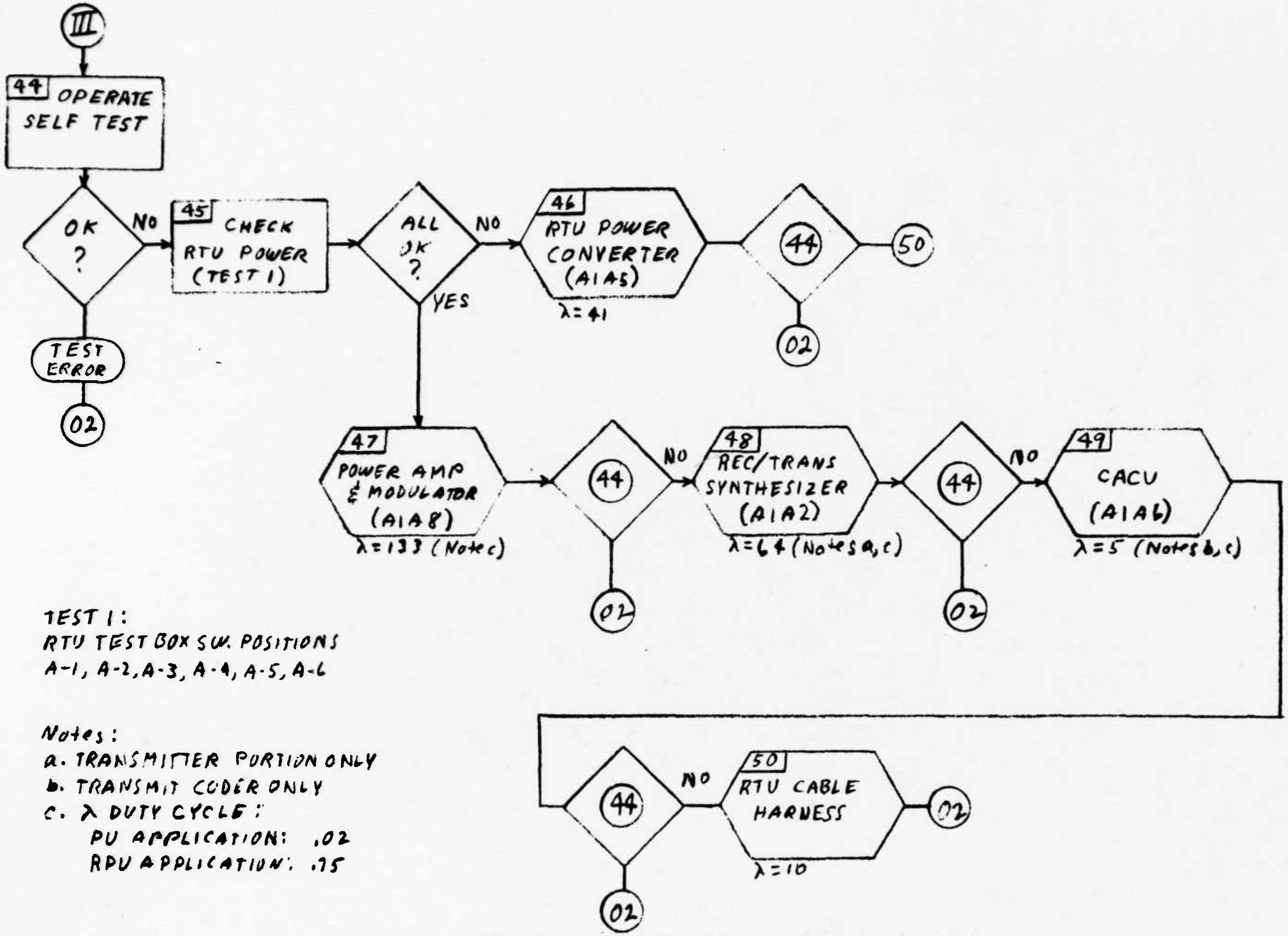
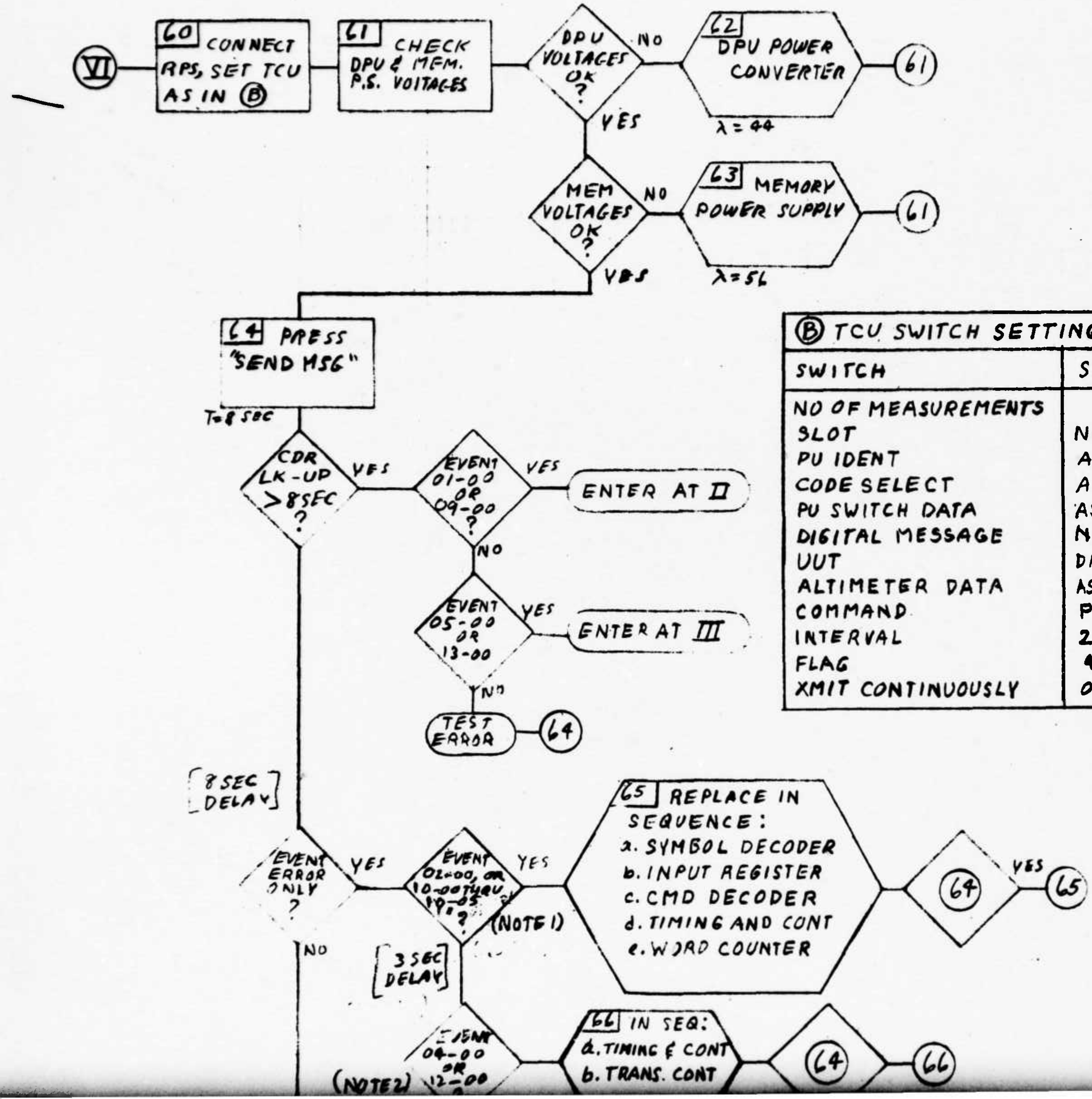


Figure G-4. RTU Maintenance Flow Diagram (Transmit Functions)



Ⓑ TCU SWITCH SETTINGS

SWITCH	SETTING
NO OF MEASUREMENTS	66
SLOT	NOT USED
PU IDENT	ALL
CODE SELECT	AS REQUIRED
PU SWITCH DATA	AS DESIRED
DIGITAL MESSAGE	NOT USED
UUT	DPU/RTU/CMU
ALTIMETER DATA	AS DESIRED
COMMAND	P1
INTERVAL	2
FLAG	4
XMIT CONTINUOUSLY	OFF

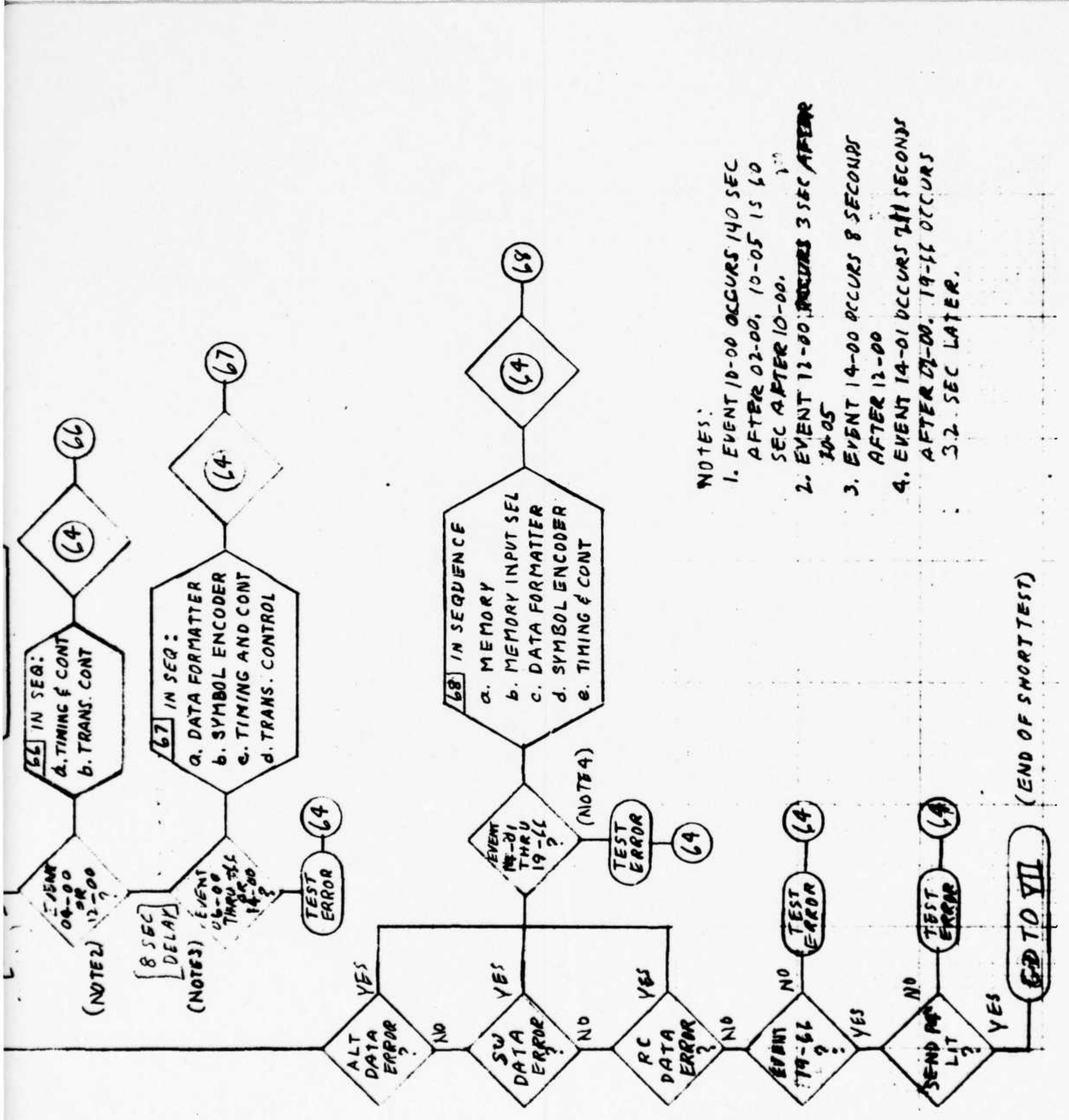


Figure G-5. Reference Position Unit Maintenance Flow Diagram

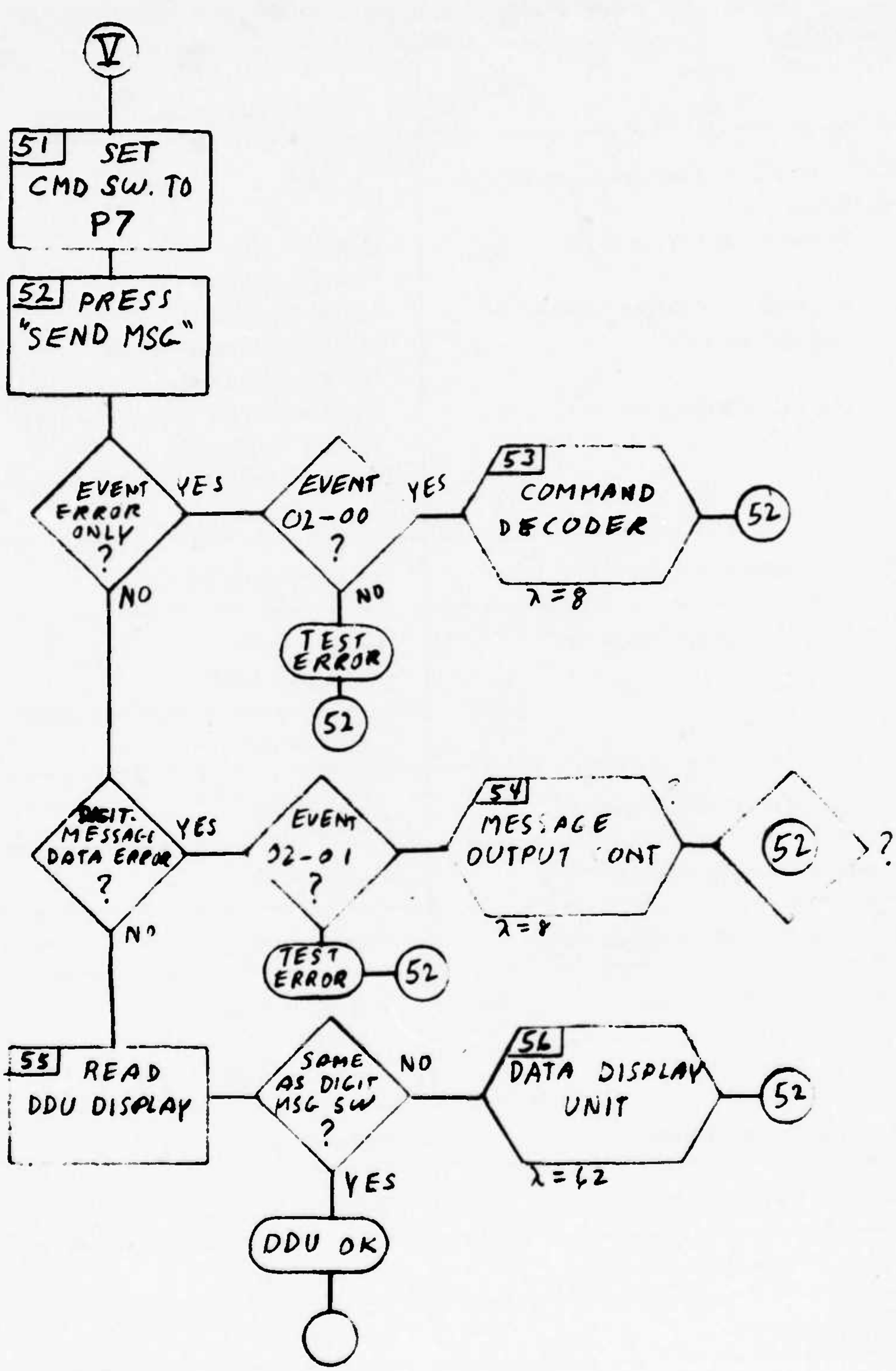


Figure G-6. Positioning Unit Supplementary Maintenance Flow Diagram (P7 Message Sequence)

Table G-1. Corrective Maintenance Task Time Estimates

Task No.	Task	Task Element	Time (Min)
01	Connect PU to Test Set, set TCU Switches		
	Remove Unit from Case	Latches (4)	0.1
		Captive Screws (4)	2.4
	Remove Protective Cover	Loose Screws (4)	3.2
	Connect to TCS	Multipin Connector (3)	5.0
		RF Connector (2)	0.8
	Operate Switches	Pushbutton on Toggle Sw (12)	1.2
		Rotary Switch (3)	0.6
		Total	13.3
02	Press "Send Message"	Press Switch +8 sec	0.3
03	Replace Command Decoder	Unplug PCB	0.9
		Exchange PCB	0.2
		Total	1.1
04	Replace Command Decoder	Same as 03	1.1
05	Replace Message Output Cont	Same as 03	1.1
06	Replace Message Output Cont	Same as 03	1.1
07	Set Cond Switch to P4	Rotary Switch	0.2
08	Press "Send Msg"	Press Switch +10 sec	0.3
09	Replace Word Control	Same as 03	1.1
10	Set End Switch to P4	Same as 07	0.2
11	Press "Send Msg"	Same as 08	0.1
12	Replace RCDV	Same as 03	1.1
13	Replace Data Assemb	Same as 03	1.1
14	Replace Memory	Same as 03	1.1

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
15	Replace Control Panel	Cannon Connector	1.6
		Exchange Panel	0.2
		Set Switches (10)	1.0
		Total	2.8
16	Check RTU Power	Rotate Switch (6 positions)	0.7
		Meter measurement (6)	1.4
		Total	2.1
17	Replace RTU Power Conv	Cannon Connector (2)	6.6
		Captive Screw (4)	4.8
		Exchange Module	0.2
		Total	11.6
18	Set Xmit Cont to CONT	Flip Switch	0.1
		Wait 10 seconds	0.2
		Total	0.3
19	Replace Rec-Trans Synth	Cannon Connector	3.3
		RF Connector (6)	3.0
		Captive Screw (2)	2.4
		Exchange Module	0.2
		Total	8.9
20	Interrupt Transmit	Press Button	0.1
		Wait 10 seconds	0.2
		Total	0.3
21	Set Xmit Cont to OFF	Flip Switch	0.1
22	Check Carrier IQ	Rotate Switch (3 positions)	0.4
		Scope measurement (2)	0.7
		Meter measurement	0.4
		Total	1.5

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
23	Replace RF/IF	Cannon Connector	3.3
		RF Connectors (5)	2.5
		Captive Screws (2)	2.4
		Exchange Module	0.2
		Total	8.4
24	Replace Carrier IQ Loop	Cannon Connector	3.3
		RF Connectors (6)	3.0
		Captive Screws (2)	2.4
		Exchange Module	0.2
		Total	8.9
25	Replace CACU	Cannon Connector	3.3
		RF Connector (9)	4.5
		Captive Screws (4)	4.8
		Exchange Module	0.2
		Total	12.8
26	Check Code Lock	Rotate Switch	0.2
		Meter measurement	0.4
		Total	0.6
27	Replace Code Detector	Cannon Connector	3.3
		Captive Screws (2)	2.4
		Exchange Module	0.2
		Total	5.9
28	Replace CACU	See Task 25	12.8
29	Check Carrier Lock	Rotate Switch	0.2
		Meter measurement	0.4
		Total	0.6
30	Replace Carrier IQ Loop	See Task 24	8.9

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
31	Interrupt Transmit	See Task 20	0.3
32	Replace CACU	See Task 25	12.8
33	Replace Code Detector	See Task 27	5.9
34	Replace CACU	See Task 25	12.8
35	Interrupt Transmit	See Task 20	0.3
36	Check Delayed Clock Lock	Rotate Switch	0.2
		Meter measurement	0.4
		Total	0.6
37	Replace Clock Ph Cont Loop	Cannon Connector	3.3
		RF Connectors (6)	3.0
		Captive Screws (2)	2.4
		Exchange Module	0.2
		Total	8.9
38	Interrupt Transmit	See Task 20	0.3
39	Replace CACU	See Task 25	12.8
40	Replace Code Detector	See Task 27	5.9
41	Replace CACU	See Task 25	12.8
42	Interrupt Transmit	See Task 20	0.3
43	Replace RTU Cable Harness	Cannon Connectors (11)	36.3
		RF Connectors (34)	17.0
		Total	53.3
44	Operate Self Test	Pushbutton	0.2
		Wait 8 seconds	0.1
		Total	0.3

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
45	Check RTU Power	See Task 16	2.1
46	Replace RTU Power Connector	See Task 17	11.6
47	Replace PA & Modulator	Cannon Connector RF Connector (3) Captive Screws (6) Exchange Module	3.3 1.5 7.2 0.2
		Total	12.2
48	Replace Rec-Trans Synth	See Task 19	8.9
49	Replace CACU	See Task 25	12.8
50	Replace RTU Cable Harness	See Task	53.3
51	Set Cond Sw to P7	Rotate Switch	0.2
52	Press "Send Msg"	Press Button	0.1
53	Replace Command Decoder	Unplug-Plug PCB Exchange PCB	0.9 0.2
		Total	1.1
54	Replace Message Output Cont	Same as Task 53	1.1
55	Read DDU Display	Digital Readout (10)	0.2
56	Replace DDU	Exchange Unit Multipin Connector	0.2 3.3
		Total	3.5
60	Connect RPS to Test Set, Set Switches Remove Units from Cases	Captive Screws (8) Slide Unit out (2) (est)	4.8 0.2

Table G-1. Corre[illegible]e Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
60 (cont)	Connect to TCS	Multipin Connector (4)	6.6
		RF Connector (2)	0.8
	Operate Switches	Push Button on Toggle (12)	1.2
		Rotary Switch (3)	0.6
		Total	14.2
61	Check DPU & Memory Voltages	Meter measurements (5)	1.2
62	Replace DPU Power Converter	Unplug, Plug PCB	0.9
		Exchange PCB	0.2
		Total	1.1
63	Replace Memory P.S.	Captive Screws (4)	2.4
		Unplug-Plug Unit	0.9
		Exchange Unit	0.2
		Total	3.5
64	Press "Send Message"	Same as 02	0.3

Table G-2. Positioning Set Task Time Summary

Replaceable Item	Task #	T	λ	$\Sigma\lambda T$
Command Decoder (Decode S1)	01	13.3		
	02	0.3		
	Delay	0.3		
	03	1.1		
	02	0.3		
		15.3	8	122
Command Decoder (UUT Transmit on)	01	13.3		
	02	0.3		
	Delay	0.3		
	04	1.1		
	02	0.3		
		15.3	8	122

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Task #	T	λ	Σλ T
Message Output Cont (UUT Transmit on)	01-04 02 Delay 05 02	15.0 0.3 0.3 1.1 0.3		
		17.0	8	136
Message Output Cont (Encode S5)	01-02 Delay 06 07 08	13.6 0.4 1.1 0.2 0.3		
		15.6	8	125
Word Control (Encode S5)	01-08 Delay 09 08	15.6 0.4 1.1 0.3		
		17.4	8	139
RCDU	01 02 Delay 10 11 12 11	13.3 0.3 0.1 0.2 0.1 1.1 0.1		
		15.2	20	304
Data Assemb (RC Error)	01-12 & 11 13 11	15.2 1.1 0.1		
		16.4	8	131
Memory (RC Error)	01-13 & 11 14 11	16.4 1.1 0.1		
		17.6	1	18

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	T	T	λ	ΣλT
Control Panel	01	13.3		
	02	0.3		
	Delay	0.3		
	15	2.8		
	02	0.3		
		17.0	108	1840
RTU Power Conv (Receive Problem)	01, 02	13.6		
	16	2.1		
	17	11.6		
	16	2.1		
	02	0.3		
		29.7	41	1220
Rec-Trans Synth (Receive)	01-16	15.7		
	18	0.2		
	19	8.9		
	20	0.2		
		25.0	56	1400
RF/IF Amp	01-20	25.0		
	22	1.5		
	23	8.4		
	20	0.2		
		35.1	18	640
Carrier IQ Loop (Code Search)	01-23 & 20	35.1		
	24	8.9		
	20	0.2		
		44.2	26	1150
CACU (Code Search)	01-24 & 20	44.2		
	25	12.8		
	20	0.2		
		57.2	10	572
CACU (Status Output)	01-20	25.0		
	22	1.5		
	26	0.6		
	28	12.8		
	20	0.2		
		40.1	5	205

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Task #	T	λ	Σ λ T
Code Detector (Code Search)	01-22 26 27 20	26.5 0.6 5.9 0.2		
		33.2	13	432
Carrier IQ Loop (Carrier Search)	01-18 29 30 31	15.9 0.6 8.9 0.3		
		25.7	26	670
CACU (Carrier Search)	01-31 32 31	25.7 12.8 0.3		
		38.8	10	388
Code Detector	01-32 & 31 33 31	38.8 5.9 0.3		
		45.0	5	225
CACU (Status Output)	01-29 34 35	16.5 12.8 0.3		
		29.6	5	148
Clock Phase Control	01-18 36 37 38	15.9 0.6 8.9 0.3		
		25.7	64	1640
CACU (Clock Adj)	01-38 39 38	25.7 12.8 0.3		
		38.8	10	388
Code Detector (Delay Circuit)	01-39 & 38 40 38	38.8 5.9 0.3		
		45.0	2	90

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Task #	T	λ	$\Sigma\lambda T$
CACU (Status Output)	01-36	16.5		
	41	12.8		
	42	0.3		
		29.6	5	148
RTU Power Converter (Transmit Problem)	01, 02	13.6		
	44	0.3		
	45	2.1		
	46	11.6		
	44	0.3		
		27.9	41	1140
PA and Modulator	01-45	16.0		
	47	12.2		
	44	0.3		
		28.5	133	3790
Rec/Trans Synth (Transmit)	01-47 & 44	28.5		
	48	8.9		
	44	0.3		
		37.7	64	2420
CACU (Trans Code)	01-48 & 44	37.7		
	49	12.8		
	44	0.3		
		50.8	5	254
Totals			706	19,857

$$\overline{M}_{ct} = \frac{19857}{706} = 28.3 \text{ minutes}$$

Replaceable Item	Task #	T	λ	$\Sigma\lambda T$
DDU	01-02	13.6		
	Delay	0.3		
	51	0.2		
	55	0.2		
	56	3.5		
Totals		17.8	62	1100

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only)

Replaceable Item	Task #	T	λ	ΣλT
DPU Power Converter	60	14.2		
	61	1.2		
	62	1.1		
	61	1.2		
		17.7	44	780
Memory Power Supply	60-61	15.4		
	63	3.5		
	61	1.2		
		20.1	56	1120
RTU Power Converter (Receive Problem)	60	14.2		
	61	1.2		
	64	0.3		
	16	2.1		
	17	11.6		
	16	2.1		
	64	0.3		
		31.8	41	1300
Rec-Trans Synth (Receive)	60-64	15.7		
	16	2.1		
	18	0.3		
	19	8.9		
	20	0.3		
		27.3	56	1530
RF/IF Amp	60-64, 16-20	27.3		
	22	1.5		
	23	8.4		
	20	0.3		
		38.5	18	690
Carrier IQ Loop (Code Search)	60-23 & 20	38.5		
	24	8.9		
	20	0.3		
		47.7	26	1240

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only) (Cont)

Replaceable Item	Task #	T	λ	ΣλT
CACU (Code Search)	60-24 & 20	47.7		
	25	12.8		
	20	0.8		
		61.3	10	613
CACU (Status Output)	60-20	27.3		
	22	1.5		
	26	0.6		
	28	12.8		
	20	0.3		
		42.5	5	212
Code Detector (Code Search)	60-22	28.8		
	26	0.6		
	27	5.9		
	20	0.3		
		35.6	13	463
Carrier IQ Loop (Carrier Search)	60-18	18.1		
	29	0.6		
	30	8.9		
	31	0.3		
		27.9	26	725
CACU (Carrier Search)	60-31	27.9		
	32	12.8		
	31	0.3		
		41.0	10	410
Code Detector	60-29	18.7		
	33	5.9		
	31	0.3		
		24.9	5	124
CACU (Status Output)	60-29	18.7		
	34	12.8		
	35	0.3		
		31.8	5	159

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only) (Cont)

Replaceable Item	Task #	T	λ	Σλ T
Clock Phase Control	60-18	18.1		
	36	0.6		
	37	8.9		
	38	0.3		
		27.9	64	1790
CACU (Clock Adj)	60-38	27.9		
	39	12.8		
	38	0.3		
		41.0	10	410
Code Detector (Delay Circuit)	60-39 & 38	41.0		
	40	5.9		
	38	0.3		
		47.2	2	94
CACU (Status Output)	60-36	18.7		
	41	12.8		
	42	0.3		
		31.8	5	159
RTU Power Converter (Transmit Problem)	60-64	15.7		
	44	0.3		
	45	2.1		
	46	11.6		
	44	0.3		
		30.0	41	1230
PA & Modulator	60-45	18.1		
	47	12.2		
	44	0.3		
		30.6	133	4070
Rec/Trans Synth (Transmit)	60-47 & 44	30.6		
	48	8.9		
	44	0.3		
		39.8	64	2550

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only) (Cont)

Replaceable Item	Task #	T	λ	$\Sigma\lambda T$
CACU (Transmit Coder)	60-48 & 44	39.8		
	49	12.8		
	44	0.3		
		52.9	5	264
Totals			639	19,933

$$\overline{M}_{ct} = \frac{19933}{639} = 31.2$$

Table G-4. RPS Fault Detection Time

Type of Operation	Time After Starting Test		
	Minimum	Maximum	Average
Decoding & Responding to Commands	0.1	3.0	1.55
Generating & Transmitting Commands	0.4	3.8	2.0
All Logic Modules	0.1	3.8	1.95
Exercising Memory	3.8	4.0	3.9

Table G-5. Elemental Task Times

Task Element	One-way Time	Data Source
Fastener Operation		
Loose Screw with Washer	0.8	NAVSHIPS 94324
DZUS Fasteners	0.05	NAVSHIPS 94324
Captive Screw	0.60	NAVSHIPS 04324
Latches	0.03	NAVSHIPS 94324
Connector Operation		
Multipin Connector (Cannon Connector, etc.)	1.65	
(Plug-in)	(0.45)	MIL-HDBK-472
(2 Captive Screws)	(1.20)	NAVSHIPS 94324

Table G-5. Elemental Task Times (Cont)

Task Element	One-way Time	Data Source
RF Connector	Disconnect 0.1 Reconnect 0.4	Motorola Timed Data
PCB	0.45	NAVSHIPS 94324
Module Exchange	0.20	
(Remove Module) (Place On Chassis)	0.05 0.15	Estimate MIL-HDBK-472

Task Element	1st Action	Subsequent	Data Source
Test Operations			
Observe Go-No-Go (or digital readout)	0.1	0.01	Estimated
Monitor Analog Reading (Meter)	0.4	0.2	Estimated
Monitor Digital Reading (Scope)	0.5	0.2	Estimated
Pushbotton or Flip Switch	0.1	0.1	Estimated
Rotate Knob	0.2	0.1	Estimated

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